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CONSTRUCTION AND MAINTENANCE OF AIR-  
FIELDS

G. I. Glushkov, et al

Foreign Technology Division  
Wright -Patterson Air Force Base, Ohio

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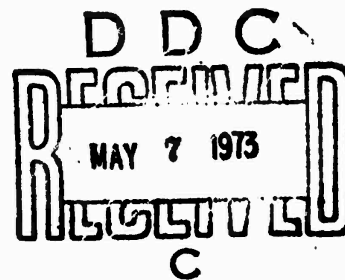
## FOREIGN TECHNOLOGY DIVISION



CONSTRUCTION AND MAINTENANCE OF AIRFIELDS

by

G. I. Glushkov and  
B. S. Rayev-Bogoslovskii



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13. ABSTRACT The manual contains the general requirements for airfields, information about their elements, about the methods and means of operational maintenance and repair of flying field and basic airport installations. Special attention is given to the unsurfaced flying strips, which are widely distributed in the system of ground aids to air transport and are set up in airports of all types of air traffic. In the book are examined contemporary constructions of hard and soft coverings, including concrete, reinforced, prestressed - monolithic and composite, asphalt-concrete and rough coverings made of crushed stone and gravel mixtures, and also sectional coverings. Snow and ice coverings on airfields are described. The principles of calculations of the basic constructions of the flying zone are presented; a new calculation procedure is given for artificial bases of airfield coverings. Special attention is given to the reconstruction of hard and soft types of coverings, to the maintenance and repair of unsurfaced flying strips and to the winter maintenance of airfields. The manual content corresponds to the standard documents in force. The manual is intended for students of specialized technical schools and can be used by technical personnel for airports, who are engaged in the servicing and the operational maintenance of airfields.		

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textbook for technical high schools and a  
training aid for courses of raising the skill  
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### ACRONYMS

MC = MS = parking place  
PD = RD = taxiway  
BПП = RW = runway  
KДП = KDP = control tower  
OПП = OPP = main direction-finding station  
ATБ = ATB = motor pool  
БПБ = BPB = lateral clear zone  
KПБ = KPB = overrun  
CДП = SDP = sanitary and decontamination station  
БПРМ = BPRM = inner marker beacon  
ДПРМ = DPRM = outer marker beacon  
ATC = ATS = automatic telephone exchange  
ГCM = GSM = fuels and lubricants  
ЦЗC = TsZS = centralized aircraft fueling  
ЛЕР = LEP = expansion unknown  
ТП = TP = expansion unknown  
ЛП = LP = flying strip  
ГП = GP = dirt strip

ГЛП = GLP = dirt flying strip  
МГА = MGA = Ministry of Civil Aviation  
ПК = PK = forward edge  
ГОСТ = GOST = All-Union State Standards  
ЧМТУ = ChMTU = technical specification for ferrous metallurgy  
РБВ = RBV = rubber asphalt binding agent  
ОВИ = OVI = high intensity lights  
ОСИ = OSI = medium intensity lights  
ОСП = OSP = instrument-landing equipment  
ТУ = TU = technical specification  
СНП = SNIP = construction norms and regulations  
НП = NIP = norms and regulations  
Г.Г.В. = G.G.V. = ground-water level  
СЦБ = STsB = signallization, centralization block system  
СН = SN = construction norm  
ГВФ = GVF = Civil Air Fleet  
ГМС = GMS = group parking place  
НПМ = KPM = combination sprinkling and washing machine

*The manual contains the general requirements for airfields, information about their elements, about the methods and means of operational maintenance and repair of flying field and basic airport installations. Special attention is given to the unsurfaced flying strips, which are widely distributed in the system of ground aids to air transport and are set up in airports of all types of air traffic.*

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*Tables 70, Figs. 142, Bibliography 19.*

## INTRODUCTION

In proportion to the development of the aircraft fleet the requirements for airfields and their basic elements were changed in the course of time, since they are determined to a considerable degree by the dimensions, weight and takeoff and landing characteristics of the aircraft based at these airfields, and also by the features of their maintenance and repair.

In 1922 from Moscow to the first Soviet fair in Lower Novgorod (distance of 420 km) the aircraft "Il'ya Muromets" laid out the first air line in our country. In a year scheduled air service began on this route.

From the number of the firstlings of civil aviation it is necessary to indicate the A. N. Tupolev aircraft ANT-9. A miracle of aviation technology was considered the five-engined aircraft ANT-14 and the eight-engined ANT-20 ("Maxim Gorkiy").

In 1939 Aeroflot was supplemented by the six-engined "USSR-L-760" aircraft, which received the designation PS-124 - the largest all-metal land aircraft in the world. In 1938 the aircraft Li-2, utilized on local lines, was created. Due to the simplicity of construction, handling and servicing it conquered the wide recognition of the flight, engineering and technical personnel of Aeroflot.

However the most substantial development of the Civil Air Fleet occurred in the postwar years.

In 1946 flights of the Il-12 passenger aircraft (designer S. V. Il'yushin) began. From 1948 in the Civil Air Fleet the aircraft An-2 (designer O. K. Antonov) began to be operated. This aircraft is widely used for the most various purposes, especially in agriculture.

In 1954 began the routine transportation of passengers on the Il-14 aircraft, the first mass aircraft of Aeroflot, completely equipped with all the necessary modern flight equipment for flights at any time of day. The Il-14 aircraft is widely used on the airlines of medium and short length.

In 1955 the first domestic passenger turbojet aircraft Tu-104 (designer A. N. Tupolev) was lifted into the air, and from 1956 on it began the mass transportation of passengers, having substantially outstripped the foreign airlines.

In 1959 the most widespread heavy passenger aircraft in the USSR with turboprop engines, the Il-18, emerged on air line. In the same year 1959 the turboprop aircraft An-10 entered Aeroflot. Despite the considerable weight the aircraft An-10 can perform flights from unsurfaced airfields.

Since 1962 along the Moscow-Khabarovsk route flies the giant turboprop aircraft Tu-114. In 1964 it laid out the longest nonstop Aeroflot line between Moscow and Cuba. These machines also fly to Japan, Canada, India and other countries.

Since 1962 on the Aeroflot routes the turbojet aircraft Tu-124 and turboprop An-24, intended for the servicing of lines of medium length, have been operated. The Tu-124 was replaced by the Tu-134 aircraft, which is distinguished by a more modern construction.



In 1965 the An-22 aircraft was created, which is able to accomplish flights from unpaved airfields. In 1966 this aircraft lifted a load weighing 88,103 kg to altitude 6500 m, having set several world records.

In 1967 for servicing the local Aeroflot lines the Yak-40 turbojet aircraft (designer A. S. Yakovlev) was created. It can perform flights from natural-surface runways.

In 1967 the unique aircraft-microbus Be-30 (designer G. M. Beriyev) with two turbineprop engines was created. The aircraft is intended for servicing the lines of short length. It can take off from unpaved runways.

The largest of the Aeroflot turbojet airships is the Il-62 aircraft, being operated on air routes of considerable range, including between continents. The aircraft possesses good takeoff and landing characteristics.

The Tu-154 aircraft was created, which is intended for gradual replacement of Tu-104, Il-18 and An-10 aircraft on air lines.

For air routes of considerable range the Tu-144 aircraft was created - the first Soviet supersonic passenger airship. It has speeds up to 2500 km/h, ceiling 20,000 m, flying range 6500 km.

All the modern aircraft of civil aviation are subdivided into groups:

I - long-range main airliners with 160-200 seats (Tu-144, Il-62, Tu-114, An-22 and others);

II - medium main airliners with 100-160 seats (Tu-154, Tu-104, Il-18, An-10 and others);

III - short-range main airliners (Tu-124, Tu-134 and others) and large aircraft of local lines with 30-100 seats (An-24 and others).

IV - medium and light aircraft of local lines up to 30 seats (Yak-40, Be-30, An-2 and others).

The characteristics of the aircraft, which are necessary for the airfield builder (take-off weight, cruising speed), have the following values:

Type of aircraft	Take-off weight, kg	Cruising speed, km/h
ANT-9.....	6200	222
ANT-20.....	42,000	200
Li-2.....	10,700-11,500	250
Il-12.....	17,250	300
An-2.....	5250	180-210
Il-14M.....	17,500	280-350
Tu-104A, Tu-104B.....	76,000	750-800
Il-18A, Il-18B, Il-18C, Il-18D.....	58,700-64,000	630-650
An-10.....	56,000	600-660
Tu-114.....	173,500	750
An-24.....	21,000	450
Tu-124.....	38,500	750-800
Il-62.....	160,000	850-870
Tu-134.....	44,000	870
An-22.....	250,000	740
Yak-40.....	13,700	550
Be-30.....	5700	460-480
Tu-154.....	86,000	900

In parallel with the development of aircraft the airfield construction was developed. Beginning with the middle of the 30's the airports of a number of larger cities began to be equipped with runways with concrete artificial covering. In 1941 the first phase of the Vnukovo airport in Moscow, equipped with runways, taxiways, with air terminals and services for aircraft and passengers, went into operation.

As in aircraft construction, in airfield building large changes occurred in postwar years. These changes were connected with a sharp increase in the volumes of transporting passengers and cargo by air transport and with the advent of large and high-speed aircraft. Most modern airports have concrete or asphalt runways, designed for large aircraft. At each airport there are services for flight control, servicing the aircraft, their crews and the operational maintenance of the airport itself and the air field.

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**SECTION I**

**THE CONSTRUCTION OF AIRFIELDS**

## CHAPTER I

### CLASSIFICATION AND BASIC ELEMENTS OF AN AIRPORT

The constant route of scheduled flights of transport planes between populated points is called the *air line*, the path, along which the flight is accomplished, the air route, and its projection to the Earth's surface - *the ground route of the air line*.<sup>1</sup> Taking into account the unavoidable deviations of aircraft in flight, as the ground route of the air line we conditionally take a strip approximately 30 km wide - 15 km on each side of the air route.

Depending on the designation in the USSR we distinguish main, union, local and international lines. The main air lines - lines of long length, connect the capital of the Soviet Union with the large populated points of republican or regional value. Union lines connect republican, regional and district administrative, agricultural and cultural centers. Local air lines connect district and regional centers and large populated points with the regional centers and distant populated points, and also the regional centers and small populated points together.

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<sup>1</sup>Mogilevskiy D. A., Babkov V. F. and others. The Searching and Planning of Airfields, Avtotransizdat, 1963.

International lines provide the air traffic of the Soviet Union with foreign countries.

The scheduled flights of transport aviation require special equipment of the air lines, the basis of which is airports. The airport is the air transport enterprise which accomplishes routine reception and dispatching of passengers, cargo, mail and provides the organization of flights and the servicing of aircraft (Fig. 1). The airport includes the airfield and the servicing and technical area. Outside the area of the airport are located the objects of radio navigation, landing, flight control and the other operating constructions.

The 24-hour operation of airfields and their use by large high-speed aircraft are possible only with strong coverings of the runways (RW), the taxiways (RD) and the aircraft parking places (MS). At present at the airfields the hard types of coverings are most common. Also asphalt and sometimes other types of coverings are widely used.

For the round-the-clock operation of transport aviation, especially at night and in severe weather conditions (fog, low cloud cover, snowfall, rain), the airfields are equipped with electronic and illumination facilities for flight operation at airfields and flight control in the air.

For the uninterrupted supply of airports with fuel, operational materials and equipment, being required in large quantities, rail siding tracks are laid, which link the airports with the nearest railroad stations. The problems of the operational provision of the transport operation of airports and maintaining the aircraft park in working order require the construction of special buildings and constructions of well equipped hangars - workshops with servicing structures for the repair of aircraft.

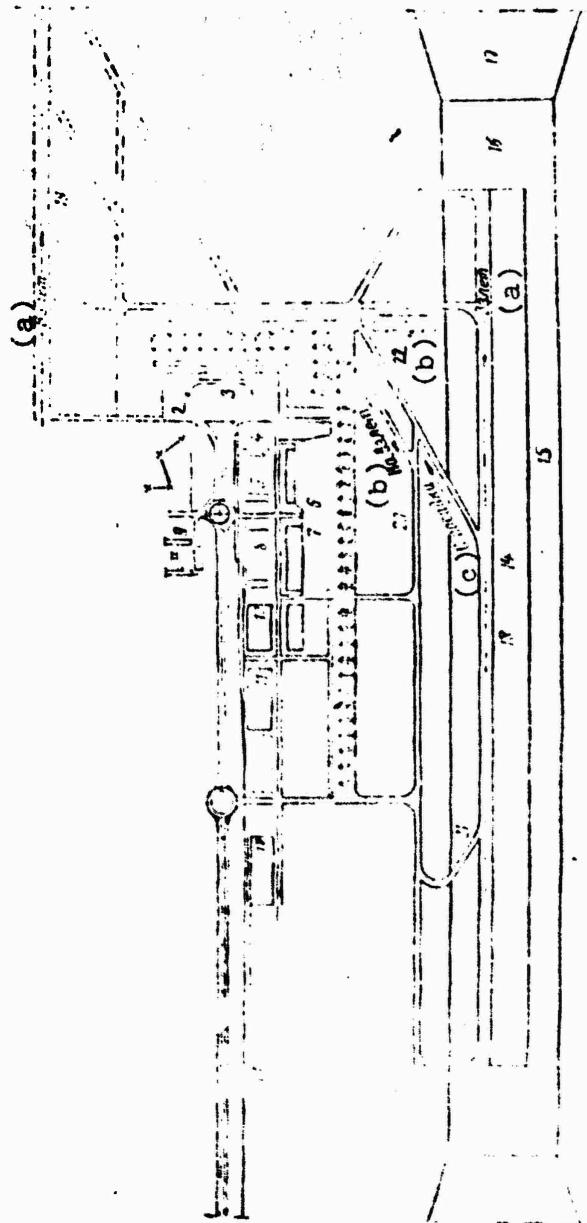


Fig. 1. Diagram of the general layout for an airport of the I class (solid lines - the first stage of building, dot-dash - future development): 1 - passenger ramp; 2 - terminal area; 3 - air terminal; 4 - KDP (control tower); 5 - control building; 6 - cargo terminal area and OPP; 7 - ATV; 8 - warehouses; 9 - hotel; 10 - area of servicing structures; 11 - area of the mechanization base and airfield yard; 12 - fuel lubricant warehouse; 13 - railway spur; 14 - flying strip with sod coverings; 15 - lateral clear zone (BPP); 16 - overrun (KPB); 17 - approach corridor; 18 - runway No. 1 with artificial coverings (RW); 19 - runway No. 2 with artificial coverings; 20 - main taxiway (MS); 21 - connecting taxiway; 22 - auxiliary taxiway.

KEY: (a) Takeoff; (b) To takeoff; (c) From landing.

For the accommodation of official personnel of the airport we construct official, administrative, culture-and-welfare and municipal buildings.

#### § 1. AIRPORTS

Airports are *land*, intended for landplanes with wheel or ski landing gears, and *seaports*, intended for seaplanes. For abbreviation we usually call the first simply airports.

Depending on the volume of the transport operation being fulfilled, the handling capacity, perfection of equipment, and class of airfield the transport airports of civil aviation are subdivided into five classes (Table 1).

Table 1.

Class of airport	Annual volume of passenger transportation per exchange, thous. of people	Class of airfield
I = A	1700-3500	A
II = B	800-1700	B
III = C	250-800	C
IV = D	50-250	D
V = E	20-50	E

Airports with annual volume of transportation more than 3500 thous. people are considered as nonclass and are set up according to individual requirements. Airports with annual volume of passenger transportation less than 20 thous. people should pertain to unclassified; they are designed on the strength of local requirements for their operation, and also the possibility of realization of building.

The intensity of aircraft traffic to the airport is expressed in pairs (takeoff-landing) for a certain time interval. For



airports of various classes the tentative intensity of traffic of various groups of aircraft is presented in Table 2.

Table 2.

Class of airport	Class of airport				
	I=A	II=B	III=C	IV=D	V=E
	Quantity of pairs of aircraft in a 24-hour period				
I	5-10	-	-	-	-
II	32-63	18-37	6-14	-	-
III	63-127	32-63	6-35	2-10	-
IV	-	-	8-21	8-40	7-16

With respect to purpose we distinguish international, union and local airports. International airports are open for international air traffic and are specially equipped for the reception (dispatching) of passengers and cargo because of the border. Airports of union value are located on union or main air lines. International airports and airports of union value, at which are operated high-speed passenger aircraft with high takeoff weight, should provide year-round operation under severe weather conditions. Such airports have the most modern equipment. The airports of local air lines, which the aircraft of light or medium types are operated, usually have the minimum necessary equipment for accomplishing flights in the day and night time.

Airfields most frequently have a dirt matted surface and a RW made of packed soils or with coverings of the lowest types.

For each new or reconstructed airport there are compiled technical and economical substantiations, determining the list and characteristics of constructions which should be at the airport.

This list should consider the prospect for development 10 years after the planned period of introduction of the airport into operation. The nomenclature of buildings, constructions and equipment of the airport depending on its class is given in Table 3.

As the first stage of building it is permitted to place into operation a "starting complex" of constructions and equipment, which can insure the beginning of safe accomplishment of takeoff and landing operations.

Table 3.

Name	Class of airport									
	I		II		III		IV		V	
	complete complex	starting complex	complete complex	starting complex	complete complex	starting complex	complete complex	starting complex	complete complex	starting complex
1	2	3	4	5	6	7	8	9	10	11

Airfield										
RW (with artificial covering)	+	+	+	+	+	+	+	-	+	-
Main RD	+	-	+	-	+	-	-	-	-	-
Connecting and auxiliary RD	+	+	+	+	+	+	+	+	+	+
Passenger ramp	+	+	+	+	+	+	+	+	+	+
MS for storage and operational types of aircraft maintenance	+	-	+	-	+	-	+ <sup>2</sup>	-	+ <sup>2</sup>	-

Table 3 (Cont'd.).

1	2	3	4	5	6	7	8	9	10	11
MS for washing of aircraft	+	-	+	-	+	-	+	-	+	-
MS for periodic types of maintenance and finishing of aircraft	-	-	-	-	+ <sup>7</sup>	-	+ <sup>7</sup>	-	+	-
MS for special-purpose aviation	-	-	-	-	+ <sup>3</sup>	+ <sup>3</sup>	+ <sup>3</sup>	+ <sup>3</sup>	+ <sup>3</sup>	+ <sup>3</sup>
Apron and MS for aircraft finishing	+	-	+	-	+ <sup>8</sup>	-	+ <sup>8</sup>	-	-	-
Engine starting area	+	+	+	+	+	+	-	-	-	-
Area for elimination of deviation	+	-	+	-	+	-	+	-	+	-
Helipad	+ <sup>3</sup>	+ <sup>3</sup>	+ <sup>3</sup>	+ <sup>3</sup>	+ <sup>3</sup>	+ <sup>3</sup>	-	-	-	-
Reinforcement of shoulder	+	+	+	+	+	+	+	-	-	-
Ground and planning operations	+	+ <sup>1</sup>	+	+ <sup>1</sup>	+	+ <sup>1</sup>	+	+ <sup>1</sup>	+	+ <sup>1</sup>
Agrotechnical measures	+	-	+	-	+	-	+	-	+	-

Structures for servicing passenger  
and cargo transportation

Air terminal with ramp area	+	+	+	+	+	+	+ <sup>4</sup>	+ <sup>4</sup>	+ <sup>4</sup>	+ <sup>4</sup>
Cargo terminal	+	-	+	-	+	-	+ <sup>5</sup>	-	+ <sup>5</sup>	-
Airborne power supply enterprise	+ <sup>6</sup>	-	+ <sup>6</sup>	-	+ <sup>6</sup>	-	+ <sup>6</sup>	-	-	-
Section for transportation of mail	+	-	+	-	+	-	+ <sup>5</sup>	-	+ <sup>5</sup>	-
Hotel	+	-	+	-	+	-	+	-	-	-
Urban transportation station	+	-	+	-	+	-	-	-	-	-
Public toilets	+	-	+	-	+	-	-	-	-	-
Commerical pavilions	+	-	+	-	+	-	-	-	-	-

Table 3 (Cont'd.).

1	2	3	4	5	6	7	8	9	10	11
Structures and facilities for maintenance of aircraft										
Hangar housing	+	-	+	-	+3	-	+3	-	-	-
Housing for auxiliary production	+	-	+	-	+3	-	-	-	-	-
Motor pool building	-	-	-	-	+7	-	+7	-	+9	-
Hangar-shelter	-	-	-	-	+7	-	+7	-	-	-
Building for technical crews										
Stationary facilities for maintenance of aircraft on the passenger ramp	+10	+10	+10	+10	+10	+10	+10	-	-	-
	+	+	+	+	+	-	+	-	+	-
The same, on the MS	+	-	+	-	+	-	+9	-	+9	-

## Structures and facilities for radio navigation, landing and air traffic control

KDP	+	+	+	+	+	+	+	+	+4	+
SDP with weather observation point	+	+	+	+	+	+	+	+	-	-
Radio-beacon system of instrument landing approach	+	+	+	+	+	+	+	-	-	-
Marker beacon points (BPRM and DPRM)	+	+	+	+	+	+	+11	+11	+11	+11
Radars:										
surveillance	+	+	+	+	+	-	+3	-	+3	-
airfield control	+	+	+	+	+	+	+	-	+	-
precision-approach	+	+	+	+	+	+	+	-	+	-
weather	+	-	+	-	+	-	+3	-	-	-
flying field surveillance	+	-	+	-	+3	-	-	-	-	-
Automatic UHF-radio-direction finder	+	+	+	+	+	+	+	+	+	-
Electronic system of short-range navigation	+	+	+	+	+	+	+	-	+3	-
Transmitting radio center	+	+	+	+	+	+	+11	+11	+11	+11

Table 3 (Cont'd.).

1	2	3	4	5	6	7	8	9	10	11
Receiving radio center	+ <sup>12</sup>	-	+ <sup>12</sup>	-	+ <sup>12</sup>	-	-	-	-	-
Visual signal equipment with communication and control lines	+	+	+	+	+	+	+	-	+	-
Automatic telephone exchange	+ <sup>13</sup>	+ <sup>13</sup>	+ <sup>13</sup>	+ <sup>13</sup>	+ <sup>14</sup>	+ <sup>14</sup>	+ <sup>14</sup>	+ <sup>14</sup>	+ <sup>14</sup>	+ <sup>14</sup>
Communication line with the city	+	+	+	+	+	+	+	+	+	+
Line communications and radio equipment installation	+	+ <sup>1</sup>	+	+ <sup>1</sup>	+	+ <sup>1</sup>	+	+ <sup>1</sup>	+	+ <sup>1</sup>

Structures for provision of fuel  
and lubricants

Storage of GSM	+	+ <sup>1</sup>	+	+ <sup>1</sup>	+	+ <sup>1</sup>	+	+ <sup>1</sup>	+	+ <sup>1</sup>
System of TsZS	+	-	+	-	+	-	+	-	-	-

Buildings and structures of subsidiary production  
and servicing purpose

Airport and air squadron administration building with dining hall	+	+	+	+	+	+	+	-	-	-
Dining hall	+	-	+	-	-	-	-	-	-	-
Mechanization base	+	+ <sup>1</sup>	+	+ <sup>1</sup>	+	+ <sup>1</sup>	+	+ <sup>1</sup>	+	-
Fire station	+	+	+	+	+	+	+	+	+	+
Commercial laundry	+	-	+	-	+	-	-	-	-	-
Warehouse of technical equipment	+	-	+	-	+	-	+	-	+	-
Warehouse of materiel and economic implements	+	+	+	+	+	+	+ <sup>15</sup>	+ <sup>15</sup>	+ <sup>15</sup>	+ <sup>15</sup>
Tank depot	+	+	+	+	+	+	+	-	-	-
Fire-fighting equipment warehouse	+	+	+	+	+	+	+	-	-	-
Hydrogen-extraction station	+	+	+	+	+	+	+	+	-	-
Weather site	+	+	+	+	+	+	+	+	-	-

Table 3 (Cont'd.).

1	2	3	4	5	6	7	8	9	10	11
External engineering networks and structures										
LEP, TP and exterior lighting	+	+ <sup>1</sup>	+	+ <sup>1</sup>	+	+ <sup>1</sup>	+	+ <sup>1</sup>	+	+ <sup>1</sup>
Water supply	+	+ <sup>1</sup>	+	+ <sup>1</sup>	+	+ <sup>1</sup>	+	+ <sup>1</sup>	+	+ <sup>1</sup>
Sewage system	+	+ <sup>1</sup>	+	+ <sup>1</sup>	+	+ <sup>1</sup>	+	+ <sup>1</sup>	+	+ <sup>1</sup>
Combined heat and power supply networks	+	+ <sup>1</sup>	+	+ <sup>1</sup>	+	+ <sup>1</sup>	+	+ <sup>1</sup>	+	+ <sup>1</sup>
Boiler house	+	+ <sup>1</sup>	+	+ <sup>1</sup>	+	+ <sup>1</sup>	+	+ <sup>1</sup>	+	+ <sup>1</sup>
Belt lines and public service organizations										
Access railway spur	+	+	+	+	+	+	+ <sup>16</sup>	+ <sup>16</sup>	-	-
Access highway	+	+	+	+	+	+	+	+	+	+
Interairport roads and areas	+	+ <sup>1</sup>	+	+ <sup>1</sup>	+	+ <sup>1</sup>	+	+ <sup>1</sup>	+	+ <sup>1</sup>
Gardens	+	-	+	-	+	-	+	-	+	-
Barriers	+	-	+	-	+	-	+	-	+	-
Sidewalks	+	+ <sup>1</sup>	+	+ <sup>1</sup>	+	+ <sup>1</sup>	+	+ <sup>1</sup>	+	+ <sup>1</sup>

1. Is provided inside, providing the starting complex.
  2. Are combined with the passenger ramp when the assigned fleet of aircraft is present.
  3. Are provided only on special assignment.
  4. Air terminal building is interlocked or combined with the KDP building.
  5. Cargo terminal is interlocked with the mail transportation section.
  6. Are interlocked or cooperated with public power supply enterprises placed in the air terminal or other buildings. Separate building is provided only with substantiation of the impossibility of interlocking.
  7. With the absence of a hangar housing.
  8. With the presence of a hangar or hangar-shelter.
- [Footnotes continued on page 12.]

[Footnotes continued from page 11.]

9. Only with the presence of assigned aircraft.
10. With removal of the aircraft parking places from the hangar housing (ATB building) to a distance over 300 m.
11. Transmitting radio center is combined with the outer marker beacon. A separate building is provided only with substantiation of the impossibility of combining.
12. With impossibility of location in the KDP due to interference.
13. Provided in one of the airport buildings.
14. Provided in the KDP.
15. With the absence of technical equipment warehouse.
16. With technical and economic substantiation.

## § 2. AIRFIELDS

The airfield is the main element of the airport, equipped for takeoff, landing, parking and servicing of aircraft. At the airfield are located the flying strip (LP), taxiways (RD), aircraft parking place (MS), passenger ramp and various purpose areas. Within the flying strip can be located a runway (RW) with artificial covering and a dirt strip (GP).

Airfields are subdivided into six classes depending on the designed types of aircraft.

On the basis of the classification of airfields (Table 4) there are adopted the takeoff and landing characteristics of the aircraft designed for operation on the airfield being projected, on their weight taking into account its distribution on the landing gear wheels, since these characteristics determine the required dimensions of all elements of the airfield and the necessary strength of the coverings on them.

With respect to operational purpose the airfields are divided into groups:

a) the airfields of airports (transport airfields) - for utilization by aircraft of transport aviation;

b) special-purpose airfields - for accomplishing the operation of special aviation (agricultural, serving forestry, aerial survey, for the rendering of medical aid, etc.);

c) factory airfields - for flight tests of new or just repaired aircraft - should satisfy increased requirements, ensuing from the specifics of aircraft tests.

Airfields of this group are usually distinguished by long length of the runways, the best surface evenness and increased strength of coverings;

d) school airfields - for instruction or training flights of the cadets of flying academies and advanced flying schools. The equipment of the airfields of this group depends on the types of trainers and the complexity of the flight problems being solved by the educational institution;

e) club-sporting airfields, whose equipment depends on the types of the aircraft being operated, the sporting and training operations and mass measures being carried out by the aeroclub;

f) combined airfields, designed with coincidence of flight activity of different purposes at one object, for example transport and special-purpose.

With respect to the time of use all airfields are divided into constant, equipped for scheduled operation, and temporary, prepared for flights during a limited period or for the performance



of an operational mission. The temporary airfields include, in particular, ice airfields, located on the ice of rivers, lakes and seas.

Table 4.

Elements of the flying strip	Class of airfield					
	A	B	C	D	E	F
Length of overrun (KPB), m.....	400	400	400	400	250	50
Overall width of the flying strip (LP), m.	360	350	340	280	220	200
Width of effective area (LP), m.....	160	150	140	130	120	100
Including:						
a) width of dirt strip (GP), m.....	100	100	95	90	85	70
b) width of runway (RW), m.....	60	50	45	40	35	30
Width of lateral clear zone (BPB), m.....	100	100	100	75	50	50

Note: 1. Length of RW and GP, and also the design load on the covering are determined from Technical Specifications and Standards for Airfields of Civil Aviation.

2. Under crowded conditions of the airfield location a dirt strip cannot be set up.

Depending on the purpose the airfields are equipped for flights at night or daytime or under severe weather conditions.

With respect to the types of servicing of the operational flight operation of aircraft and the flying elements of the Civil Air Fleet, and also with respect to the arrangement on routes the transport airfields are base, initial (final), intermediate and auxiliary. The airfields, at which aircraft of one or several subdivisions of civil aviation are permanently based, are called bases. At these airfields the main laborious forms of maintenance and repair of aircraft are performed in planned sequence. The

laborious forms of maintenance and major overhauls of aircraft are performed at special aviation repair bases, the placement of which is not confined to any definite class of transport airfields. Initial or final are the airfields from which aircraft begin or correspondingly terminate their flights on the assigned route. Here they perform complete loading or unloading, preflight and postflight servicing of aircraft. The intermediate airfields are designed for landing of aircraft with a brief stop, provided by the schedule or assigned for flight, for the purpose of maintenance.

The auxiliary fields are intended for unforeseen landings in the case of malfunction of the aircraft or special circumstances which arose in flight.

Classification according to the nature of servicing is not connected with the classes of airports and depends only on the air lines being served. The same airfield for one line can be the base and initial (final), at the same time being intermediate or auxiliary for other air lines.

With reference of an airfield to some class and type we consider the entire complex of its operational activity, and not only the role being fulfilled with respect to any one, although important air line.

### § 3. BASIC ELEMENTS OF THE AIRFIELD

We strictly distinguish the airfield site and the airspace adjacent to it - air territory, i.e., the space above the airfield and the locality adjacent to it in a radius of approximately 50 km, within which near-airfield flights, connected with takeoffs and landings, occur.

The air territory includes air approaches to the airfield, i.e., the airspace in the direction of takeoffs and landings of aircraft.

Air approaches - the most important element of an airfield - should be free from obstructions which could make aircraft takeoff and landing difficult.

Within the airport zone we separate the holding areas, which are intended for the flights of aircraft awaiting clearances to land on instruments under severe weather conditions; large and small circles for organization of the order and safety of aircraft traffic above the airfield with good visibility; zone for training flights and test flights of aircraft under normal conditions of visibility.

#### § 4. FLIGHT ZONE

The flight zone - the main and most complex part of the airfield. It includes the air field, safety zones and approach lanes.

We call the section of ground, specially prepared and equipped for takeoffs and landings, the flying field. It should be even, free from obstructions. The requirements for the outline of the flying fields in plan ensue from the basic conditions of aircraft motion during takeoff and landing - straightness and direction against the wind. Flying fields of continuous form, which usually had outlines of regular geometric figures, were common earlier: square, convex triangle, circle or ellipse. In this case takeoff and landing are possible in any directions. The flying fields of continuous form occupy a large area, especially when the aircraft operating on them had large takeoff and landing run distances.

At the present time flying fields of continuous form can be only at airfields of the lowest groups, intended for the operation of light aircraft which have short take off and landing run distances.

The majority of modern aircraft for takeoffs and landings require considerable length of the section of ~~takeoff and landing~~ run. Besides this, artificial coverings are necessary for their year-round nonstop operation. Under these conditions the flying fields of continuous form became unsuitable. Modern aircraft withstand quite strong winds, which flow at an angle to the take-off or landing direction, so-called "cross winds." Therefore airfields began to organize the strip system. The flying strip is an elongated rectangle with ratio of sides approximately 1:8-1:7 at airfields of higher classes and 1:5-1:3 at the lowest. The flying strip allows takeoffs and landings only in two opposite directions.

Since takeoff and landing with a strong breeze, perpendicular to the axis of the flying strip, even for modern aircraft are made difficult in localities where the direction and force of the wind change very much during the different periods of the year, the necessity for the construction of several strips on the flying field can arise. At airfields with large traffic volume there are located side-by-side flying strips.

Thus, the quantity of flying strips and their arrangement in the plan for the airfield depend on the conditions of winds, the intensity of traffic, the admissibility of interruptions of the transport operation, features of the area relief and provision of free air approaches.

The clear zones are the sections of earth which border the flying field. For flying fields of strip form we distinguish the side clear zones (BPP) and overruns (KPB) (see Fig. 1).

Side clear zones increase the safety of takeoff and landing, making it possible for aircraft, having been somewhat deflected from the axis of the flying strip during the takeoff or landing run, to finish the started operation on one of the side strips. The overruns raise the safety of the flight activity during deviations from the normal takeoff or landing conditions, for example, during the inaccurate calculation of touchdown and with premature ground contact by the aircraft (before the edge of the flying strip). Overruns also decrease the danger of an emergency in cases of rolling of the aircraft beyond the flying strip during landing. Such cases can be caused by low effectiveness of brakes, especially on the slippery surface of the covering, by exceeding the landing speed, by flight past the runway end line with late touchdown, and also in cases of engine failures during takeoff (interrupted takeoff). The clear zones can be used for taxiing of aircraft, when special taxiways with artificial covering are absent at the airfield. For normal year-round and round-the-clock operation of aviation within the flight zone are located the following engineering constructions:

- a) artificial coverings of airfields (RW, RD, MS, passenger ramps and others);
- b) illumination and electronic equipment;
- c) draining and drying networks.

The taxiways with respect to purpose are divided into main, connecting and auxiliary. Main taxiways are intended for aircraft movement at takeoff or after landing along the runway - passenger ramp route. Connecting taxiways are laid out for shortening the path of movement of the landing aircraft along the airfield. Auxiliary taxiways are intended for aircraft movement in the area of passenger ramps, at parking places and at fueling points.

At airports with large traffic volume there are set up connecting RD for high-speed exit, being joined with the RW at a 30-45° angle. Width of RD is taken according to Table 5.

Table 5.

Designation of RD	Class of airfield					
	A	B	C	D	E	F
	Width of RD, m					
Main and connecting.....	22.5	21.0	18.0	16.0	14.0	10.0
Auxiliary.....	21.0	18.0	16.0	14.0	12.0	8.0

To provide for the safety of taxiing of aircraft with gas-turbine engines on their own thrust at the edges of RD are located reinforced shoulders, since the engines of these aircraft, operating over unpacked soil beyond the edge of the RD, can draw in this soil and receive damage.

Aircraft parking places (MS) - specially open areas with a strong covering, set up for aircraft located at the airfield waiting for flight.

Passenger ramps - special areas for reception and dispatching of aircraft, landing and disembarkation of passengers and for cargo handling. The ramps are passenger and cargo.

Matted dirt flying strips and clear zones can also be included in the airfield engineering structures.

The degree of investment of the airfield structures and equipment depends on the type of the aircraft being operated, the group of airfield, traffic volume and operating conditions

of the airport, and also on the necessity for insuring aircraft movement in the daytime and at night or in severe weather conditions.

The approach zones - these are sections of territory near the airfield located along the axis of the flying strip on both sides of the airfield. On the approach zones, as on the entire territory near the airfield, there should not be natural or artificial rising obstructions, which would be of danger for the aircraft taking off or coming in to land, or accomplishing flights near the airfield. On them there should be provided for safety of continuation of takeoff of the aircraft in the case of failure of one of its engines after lift-off and flights with go-around under severe visibility conditions.

By limiting the height of vertical obstructions and establishing the size of the territory, to which this limitation is extended, we consider:

a) the takeoff and landing characteristics of aircraft in the first stage of their glide and climb trajectory, and also the flight speed;

b) the direction of motion of aircraft taking off and landing. Considerably higher requirements are imposed on the aircraft takeoff and landing direction, coinciding with the longitudinal axis of the flying strip;

c) the location of obstructions relative to the direction of motion of aircraft and their distance from the flying field boundaries. As the aircraft descends and reduces the distance to the ground it is necessary that the height of the obstructions be decreased respectively;

d) aircraft landing conditions. The basic calculated case is considered instrument landing under severe weather conditions, which dictates the highest standards of limitation of the height of obstructions and size of the territory near the airfield with respect to the landing directions of aircraft.

Requirements for territory near the airfield, approach lanes and other elements of airfields are regulated by the specifications and standards.



## CHAPTER II

### FLYING FIELD RELIEF AND ARTIFICIAL AIRFIELD COVERINGS

Modern aircraft require a smooth flying strip surface, including the artificial covering. In order to create such a horizontal surface of the necessary dimensions, it would be required to do a considerable volume of earthwork, which is connected with large expenditures of forces and resources. Moreover, such a surface would not satisfy the requirements for drainage. Therefore the surface of the flying field is set up with slopes providing safe takeoff, landing and taxiing of aircraft and unimpeded water runoff.

When designing the geometric outline of the flying field surface it is necessary to preserve the outline of the natural surface as much as possible for the purpose of obtaining minimum volumes of the soil being worked out. This is attained by entry of designed surface into the natural surface of the airfield.

The relief of the flying field is determined by the following characteristics. It is accepted to call the existing (natural) surface black and define it by black marks and black horizontal lines. The planned surface is called red and is characterized by project (red) marks and red horizontal lines.

The working mark is the difference between the black and red marks; the working mark determines the depth of excavation or height of embankment; the line which connects points with identical working marks is called the isoline. The points at which black and red marks have identical value are called zero. The line which connects the zero points determines the boundaries of the earth-works and is called the line of zero operations or zero isoline.

2 The sections of the natural surface, which do not correspond to the technical requirements imposed on the relief of flying strips, are called defective places. Individual roughnesses, small in height and extent, are called microrelief.

The relief of the flying field and artificial coverings of the airfield is characterized by: amount of slopes; mating of sections with adjacent slopes; length of sections and their direction in the plan and in vertical plane.

The amount of slope of a section of the flying field is defined as the ratio of the difference of marks of adjacent points to the distance between them. The amount of slope of the surface of the flying strip is designated so as to provide safe takeoff run, holding of the aircraft over the flying strip after lift-off and before touchdown, touchdown, landing run and taxiing the aircraft, and to preserve the amount of slope required for the draining of water.

The slow runoff of precipitation leads to the overconditioning of soils and to decrease of their resistance to loads from the wheels of the aircraft. Therefore under the medium ground conditions of the northern and central strips of the European parts of the USSR the surfaces of matted dirt flying strips should be given a slope not less than 0.005. In heavy loamy and clay soils, in order to improve the conditions of surface water

drainage, an increase in the slope up to 0.007 and even up to 0.010 is admissible. With the setting of slopes it is also necessary to consider the stability of soil against erosion by melted snow and rain water. The degree of erosion depends on the intensity of the surface runoff of water, the particle-size distribution of soils, the presence and state of sod covering. For easily eroded soils (silty soils, silty and light loams, light sandy loams, fine-grained and silty sands) it is possible to allow slopes 0.010-0.015; for difficultly eroded (stony, gravelly and clay) - up to 0.020-0.030. With such slopes there is ensured the stability of the dirt surface of airfields on a good sod covering and a smooth surface. With large slopes and water consumptions special measures are necessary for the stabilization of soils - the planting of sod or paving. The maximum amounts of slope of dirt surfaces of airfields are given in Table 6.

Table 6.

Elements of airfields and their sections	Class of airfields				
	A	B, C	D	E	F
	Amount of slope				
Longitudinal slopes					
Dirt strip:					
middle section.....	0.020	0.020	0.025	0.025	0.030
end sections <sup>1</sup> :					
descending <sup>2</sup> .....	0.020	0.020	0.020	0.020	0.025
ascending.....	0.005	0.005	0.010	0.010	0.015
Overrun:					
descending <sup>2</sup> .....	0.020	0.020	0.025	0.025	0.030
ascending.....	0.005	0.005	0.010	0.010	0.015
Side clear zones:					
middle section.....	0.020	0.025	0.030	0.030	0.030
end sections <sup>1</sup> :					
descending <sup>2</sup> .....	0.020	0.025	0.025	0.030	0.030
ascending.....	0.005	0.005	0.010	0.010	0.015
Taxiway.....	-	-	0.025	0.030	0.030
Group MS.....	-	-	0.020	0.020	0.035

Table 6 (Cont'd.).

Cross slopes					
Dirt strip:					
single-slope profile.....	0.020	0.020	0.020	0.025	0.025
two-slope profile.....	0.015	0.015	0.015	0.020	0.020
Overruns:					
one-slope profile.....	0.025	0.025	0.025	0.030	0.030
two-slope profile.....	0.020	0.020	0.020	0.025	0.025
Side clear zones.....	0.025	0.025	0.030	0.030	0.030
Taxiway.....	-	-	0.025	0.025	0.030
Group MS.....	-	-	0.015	0.015	0.020

<sup>1</sup>Length of end sections of the GLP of the airfields of classes A, B and C is  $1/6 L_{n.n}$ ; D, E and F -  $1/4 L_{n.n}$  [Translator's Note:  $n.n$  = flying strip].

<sup>2</sup>The ascending and descending directions when viewing toward the working part of the GLP.

On light, well draining sandy loam, sand and gravelly soils the slopes can be decreased to 0.002-0.003. Slopes less than 0.005 are permissible also on short watershed sections of the flying strip 100-150 m on both sides from the most elevated point under the condition of a small water catchment area.

In the areas of supermoistening at airfields located on the water-logged sections of relief with insufficient slopes and unfavorable soil conditions, it is economically inexpedient to increase slopes to the minimum permissible values because of the earthworks. It is sometimes more rational to dry the flying field with the aid of drainage, draining the surface waters outside the airfield. Under this condition it is possible to allow slopes of the flying field surface lower than minimum within 0.002-0.003. The necessary ground (planning) operations should be provided for purposes of the organization of good surface runoff in the complex of the drying project.

Small slopes can be allowed also in the arid steppe and semi-arid areas with insufficient moistening, where a little or a considerable part of their deposits precipitate in the winter period (Middle and Lower Povolzh'ye, southern areas of the Ukraine).

Usually for maximum preservation of the flying strip surface the designed surface is set up curvilinear with slopes different in magnitude and direction. The diversity of the combination of slopes creates the characteristic elements of relief: relatively even sections, slopes, hillsides, watersheds, thalwegs, troughs, closed depressions (minor depressions), hills and others. A change in the direction of slope complicates aircraft takeoff and landing. For the safety of takeoffs and landings the flying strip should have smooth mating of the adjacent slopes, which are determined by the permissible surface curvature in the vertical plane.

The basic characteristic of the surface roughness is the minimum radius of curvature. The surface curvature is characterized by the value of radius  $R$  of a circular arc, passing through the salient points of the surface (Fig. 2). The surface fracture is determined by the sum of slopes, if the slopes of the adjacent sections are contrary, i.e., have mutually opposite direction. If the adjacent slopes are of one direction, i.e., cocurrent, the fracture is determined by their difference. The distance between two adjacent fractures is called the slope pitch  $a$  or the projecting pitch. The minimum projecting pitch is taken as 40 m and should not be more than 50 m.

The permissible difference of adjacent slopes is determined by the ratio of the projecting pitch to the minimum radius of curvature. The minimum permissible radii of curvature of dirt surfaces of airfields are given in Table 7.

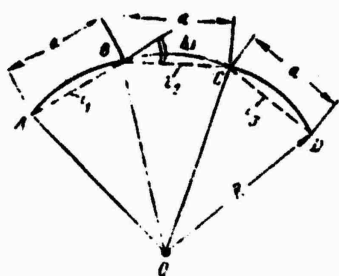


Fig. 2. Relationship between the radius of curvature of the surface and the difference of slopes:  $a$  - projecting pitch;  $i_1, i_2, i_3$  - slopes of the flying strip surface;  $\Delta i$  - algebraic difference of adjacent slopes;  $R$  - radius of curvature.

Table 7.

Element of GLP and direction of slopes	Classes of airfields	
	A, B, C	D, E and F
Effective area of GLP, km:		
in longitudinal direction.....	10.0	6.0
across.....	8.0	6.0
Side clear zone and overruns, km:		
in longitudinal direction.....	6.0	4.0
across.....	3.0	3.0

On the slopes of the RW coverings there are imposed higher requirements than for the relief of dirt flying fields with sod covering, since from them are performed flights of large aircraft, which possess high takeoff and landing speeds.

The basic characteristics of RW relief are the longitudinal and cross profiles. The longitudinal profile is the section of the RW with vertical plane passing through its axis, cross - the section of RW with vertical plane perpendicular to its axis. The longitudinal profile is designed in the form of conjugated

straight lines. It should satisfy the specifications with respect to amount of slopes, their extent, it should be smooth and provide mutual visibility of two points, located at a height of 3 m from the runway surface at a distance of not less than half the RW length.

The best surface contour of a RW with artificial covering in the cross section is considered a two-slope convex symmetrical profile with constant cross slopes over its entire length and in an extreme case on a large part (Fig. 3). Runways with such cross section are convenient for operation and are favorable for the drainage of precipitation. Runways with single-slope cross profile are set up only under extremely difficult conditions of relief (for example, in a locality which has a highly pronounced incline with slope more than 0.010 in one direction).

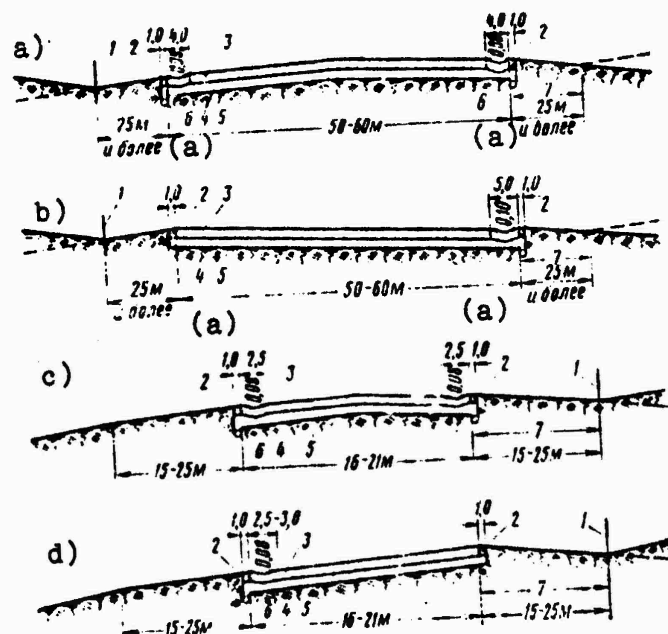


Fig. 3. Cross sections of runways and taxiways: a) two-slope profile of the runway; b) single-slope profile of the runway; c) two-slope profile of the taxiway; d) single-slope profile of the taxiway; 1 - axis of the ground trough; 2 - dirt and metal transition strip; 3 - covering; 4 - base; 5 - natural base; 6 - edge drain; 7 - dirt mating strip.  
KEY: (a) And more.

In special cases of relief on one RW there is allowed the use of both cross profiles - two-slope and single-slope. Transition from two-slope profile to single-slope is accomplished gradually by smooth displacement of the ridge in the plane of the RW.

The artificial coverings of ramps, MS and other areas are set up both with two-slope and with single-slope cross profile. The minimum value of the longitudinal slopes of the surface of the RW, RD and MS coverings sometimes cannot be restricted, since the water will drain from the coverings into closed or saw-tooth troughs, which lay at the edge of the covering. Beyond the airfield the water is drained along deep collectors, which are usually located parallel to the RW. However, with too small surface slopes the deepening of the collector, necessary for provision of minimum slopes, can be so considerable that water discharge into an open water intake will be made difficult. Thus, RW are rationally arranged so that the artificial coverings would possess minimum longitudinal slopes, necessary for water runoff along open troughs.

Table 8.

Name of slopes	Class of airfields				
	A	B, C	D	E	F
	Amount of slope				
RW					
Longitudinal slope:					
middle section.....	0.0125	0.0125	0.015	0.015	0.020
end sections:					
descending.....	0.008	0.008	0.008	0.015	0.015
ascending.....	0.005	0.005	0.010	0.010	0.015
Lateral slope:					
single-slope profile.....	0.015	0.015	0.015	0.020	0.020
two-slope profile.....	0.012	0.012	0.012	0.015	0.015



Table 8 (Cont'd.).

RD and MS					
Longitudinal slope:					
main and connecting taxiways...	0.015	0.020	0.025	0.030	0.030
auxiliary RD (on separate sections with length 200 m each)..	0.020	0.025	0.030	0.035	0.035
MS.....	0.010	0.015	0.020	0.020	0.020
Lateral slope:					
single-slope and two-slope profiles:					
RD.....	0.015	0.015	0.020	0.020	0.020
MS.....	0.008	0.010	0.010	0.012	0.012
Ramps and special areas					
Longitudinal and side slopes.....	0.008	0.010	0.010	0.012	0.012
Reinforced part of the dirt shoulders of RD, MS and ramps arranged outside the limits of the flying strips in any direction.....	0.030	0.030	0.035	0.035	0.035
The coupling of shoulders with the terrain.....	0.100	0.100	0.100	0.100	0.100

- Notes. 1. On the end sections of the RW the descending slopes should be constant (mononomical).
2. The length of the end sections of the RW with name of slopes is taken equal to; for the airfields of classes A, B, C -  $1/6$ , for the airfields of classes D, E and F -  $1/4$  of the RW length.
3. The side slopes of the RD and shoulder within the flying strips should correspond to requirements for slopes for the flying strips.
4. It is recommended to take the extent of the RW and RD sections with maximum slopes not more than 300 m.

The runoff of water along open concrete troughs is ensured with the magnitude of longitudinal slope 0.0025-0.003. The minimum longitudinal slopes of the ground troughs, which it is permitted to set up in the area of insufficient moistening or under favorable soil conditions, when precipitation drains from the coverings directly onto the adjacent dirt part of the airfield, should not be less than 0.005.

In order to accelerate the runoff of water, the minimum side slopes of coverings are taken considerably greater than the minimum longitudinal slopes, i.e., within from 0.008 to 0.012. However, on the sections of intersection with the coverings of dirt flying strips or clear zones the minimum side slopes should be decreased to 0.005 in order that the coverings would not impede flight operating on the sections of the airfield being intersected.

The maximum values of the side slopes of RW should be taken only under adverse soil, hydrogeological and climatic conditions.

The maximum value of longitudinal slopes is restricted by the requirements for safety of takeoff and landing operations, and also by the length of the RW. The maximum permissible slopes of RW, RD, MS and other areas with artificial coverings are given in Table 8, and the radii of curvature of the RW surface in longitudinal direction should be not less than those given in Table 9.

Table 9.

Class of airfield	Radius of curvature of runway surface, km	Class of airfield	Radius of curvature of runway surface, km
A	20	C	10
B	15	D, E, F	6

Note: 1. The radius of curvature of the surface of main and connecting RD and group MS in the longitudinal direction should be 6 km.

2. The radius of curvature of other areas with artificial coverings in all directions should be taken not less than 3.0 km.

The maximum longitudinal slopes on the runway are permissible only on short sections with smooth mating with the adjacent sections. The rational mating of longitudinal slopes and their alternation with respect to magnitude and extent ensue from the features of accomplishing aircraft takeoffs and landings on unsurfaced flying strips or RW.

Let us examine the case of a running take-off for climb.<sup>1</sup> The speed of the aircraft from the moment of starting will build up more intensely, the smoother the initial section of the flying strip is. If the end of the strip, opposite relative to takeoff, will be considerably raised, then the aircraft, flying in the process of acceleration at a low altitude, can in 100-200 m touch the surface of the covering with nonretracted landing gear, and shock will occur. Therefore the end sections of the flying strip should be designed with minimum slopes. The effect of longitudinal slopes is also similar during aircraft landing: the aircraft can hit against the covering if the pilot, performing the holding operation, encounters a flying strip with large opposing slope and is not able at the proper time and precisely to raise the nose. Therefore the flying strip on the section of level-out and holding should have small smooth slopes.

The landing of aircraft at a large following slope can be carried out due to the "departure" of the ground to touchdown of the aircraft considerably further than the end of landing run. Therefore on the end sections of the strip considerable slopes are adverse under the condition of landing at a slope. The best outline of the longitudinal section of the flying strip is a convex surface with small slopes on the end takeoff and landing section. In this case the aircraft will start under optimum

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<sup>1</sup>D. A. Mogilevskiy, V. F. Babkov and others. Research and Planning of Airfields. M., Autotransizday, 1963.

conditions of small surface slopes. The aircraft, which had time to gain some speed, will easily overcome the maximum slope in the middle of the flying strip and acceleration to liftoff will occur at the slope.

• A convex profile is convenient for landing. In this case the aircraft will touch down on the surface with minimum slopes.

• A decrease in the landing speed with opposing slope occurs considerably faster and finally the landing run is smoothly completed to the taxiing speed with following slopes.

## CHAPTER III

### UNSURFACED FLYING STRIPS OF AIRFIELDS

#### § 5. THE PURPOSE OF UNSURFACED STRIPS

Dirt flying strips (GLP) are areas specially prepared from local soil, intended for the accomplishment of safe takeoffs and landings. Dirt flying strips have identical purpose as RW, but they are distinguished by the fact that there is no artificial covering on them. In the system of ground provision for air transport the dirt flying strips are very widely distributed, since they are set up at airports of all types of air traffic (Fig. 4):

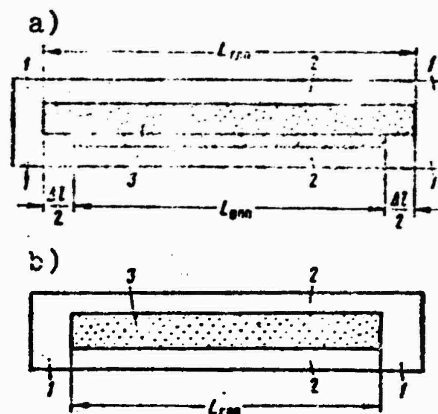
a) at airfields of classes A, B and C of international and internal air lines the GLP are set up usually along the main RW and are used as spare in the case of breakdown of the artificial coverings of RW (for example with icing of the RW surface);

b) at airfields of the local air lines of classes D, E and F not having RW with artificial coverings, the GLP is the only element of the air field providing landing and takeoff of aircraft; if on the flying field of the airfields of these classes there is created a RW with artificial covering, the GLP is set up as a spare;

c) at the spare airfields of all forms of air routes intended for unforeseen landings and subsequent takeoffs of aircraft;

d) at the airfields of the special use of aviation (agricultural, forestry, aerial survey, etc.).

Fig. 4. Dirt flying strips (GLP) depending on the class of airfield: a) airfields with artificial coverings on the RW (for airfields of class A, B, C, D -  $\Delta l = 400$  m; E -  $\Delta l = 250$  m; F -  $\Delta l = 0$ ); b) airfields which do not have artificial coverings on the RW: 1 - overrun; 2 - side clear zone; 3 - working area of dirt flying field.



Thus, depending on the class and purpose of the airport the GLP should conform to the requirements for provision of the takeoff and landing of all types of aircraft of civil aviation.

The specifications on the airports of civil aviation contain the requirements for elements of GLP (dimensions, surface slopes, etc.) taking into account the aircraft type which is designed (maximum) for this airport or airfield of the special use of aviation. The requirements for elements of GLP are somewhat different from requirements for RW with artificial coverings, which is explained by the peculiarity of the properties of soils and methods of building of areas from the soil. When designing GLP we consider the properties of the local soils, climatic, hydrological and topographical conditions of the area of construction, and also the flight conditions of aircraft at the airfield.

Fine-grain soils (sands, sandy loams and loams with organic impurities) of the surface layers possess comparatively low mechanical strength even under the most favorable conditions, i.e., with optimum humidity and after their intense packing. Therefore the surface of GLP under the action of aircraft and natural factors are unavoidably destroyed with greater or lesser intensity. After the passage of the aircraft wheels on the surface of the soil there are formed tracks, deepening with repeated passes along the same track. Under the short-term action of the gas flow of aircraft engines the particles of the surface layer of soil are raised into the air, forming a dust cloud. Under the prolonged action of gases from jet engines at rest and at start under takeoff conditions besides the formation of a cloud of dust there is possible the movement of a layer of soil several centimeters thick for several meters. The surface is eroded with the runoff of rain and thaw water, is scattered by wind. In winter on the GLP surface there are formed little knolls (swelling of soils); in spring there appear sags of highly water-saturated knolls.

In connection with the low strength and wear resistance of soil frequent and systematic repair of the GLP is necessary. With intense operation of aircraft there is necessary systematic repair of the surface in the interruptions between flights - after 100, and sometimes even 20 takeoffs and landings (depending on the aircraft type and condition of the ground). With occasional (single) takeoffs and landings of aircraft on spare GLP the repair is carried out not less than 2 times per year - in spring and in autumn. For the purpose of decrease in the accumulation of soil deformations: tracks from the aircraft wheels and blowoff by the air flows of engines, during systematic flights it is recommended to change the place of start along the width of the flying strip. Therefore the GLP are set up, as a rule, wider than the RW with artificial coverings. The prolonged effect of

the gas flow from jet engines on the takeoff sections of the GLP should be eliminated.

The resistance to the rolling of aircraft wheels along the soil in connection with the expenditure of operation for deformation of the soil (formation of tracks) is greater than when rolling over a nondeforming surface of artificial covering. The adhesion of tires of aircraft wheels with wet loamy soil is less than with a wet artificial covering. Therefore for identical conditions (local atmospheric) and characteristic of the designed aircraft the length of the GLP should be somewhat greater than the RW with artificial covering.

The operational qualities of the GLP can be sharply changed during one year in connection with the annual conditions (Fig. 5).

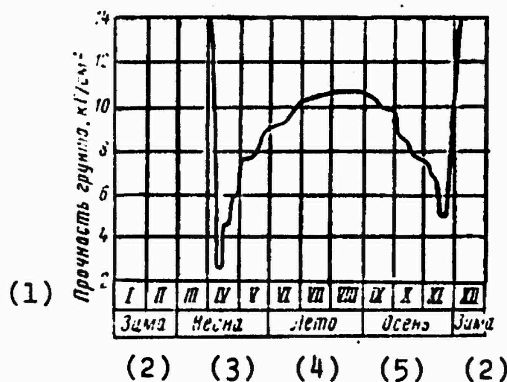


Fig. 5. Chart of change in the soil strength of the GLP during a year.

KEY: (1) Soil strength,  $\text{kgf/cm}^2$ ; (2) Winter; (3) Spring; (4) Summer; (5) Autumn.

In the dry periods of the year the flying strips on cohesive soils possess sufficient strength for the movement of all modern aircraft of civil aviation. When a well developed sod covering and low intensity of flights are present, the dust formation under these conditions can be insignificant. The aircraft motion over the frozen soil in winter (cleaned of snow) also does not cause special complications. However, during the periods of moistening

of soil in the spring and autumn, and also after lingering rains in summer the strength of soils is lowered, sometimes so much that the wheels of aircraft bog down, forming deep tracks, in consequence of which flights become impossible. In a number of



cases considerable complications to aircraft movement are exerted by the contamination of landing gear, fuselage and airframe by liquified soil, being thrown out from the tracks by the wheels. The pieces of soil can enter the aircraft engines. The period of sharp lowering of the soil strength is called the period of bad road conditions. In the middle band of the Soviet Union are pronounced spring and autumnal bad road conditions, and in rainy years also a brief summer. In the southern part of the USSR and in the Central-Asiatic republics due to frequent thaws and insignificant depths of soil freezing the autumnal bad road conditions are frequently drained off with spring.

The speed of the soaking of soils of the flying field depends on the grain-size distribution of the soil, area relief and degree of compaction of the soil. On the sections of the flying field with increased slopes and even surface (the absence of small minor depressions and tracks from the wheels of transport) the fallen precipitation drains off and the soil absorbs considerably less water than on sections with uneven surface and small slopes. The more highly the soil is packed, the less the volume of pores in it and the smaller the quantity of free and capillary moisture, which most sharply lowers the resistance of soil to loads, that can be contained. Friable and insufficient packed soil rapidly becomes soaked; with the passage of the aircraft wheels on such soil deep tracks are formed and the resistance to the rolling wheels considerably increases.

Spring bad road conditions begin from the start of the thawing of soil after the snow cover comes off. They usually cease after complete thawing and drying of the upper layer of soil to a depth of 30 cm. The soaking and reduction of the bearing capacity, of soil during the spring period is considerably more intense than in autumn and in summer. This is explained by the fact that before spring thawing the soil to a depth of about  $\frac{1}{3}$  the depth of freezing (to 25-40 cm) becomes saturated with ice caps, which

were formed in winter as a result of the drawing up of moisture from the lower layers. The volume of ice caps often exceeds the volume of pores (knolls, swells). Therefore with thawing the soil becomes not only water-saturated, but also friable. In the process of thawing in the spring the percolation of water from the surface layers into the underlying layers is hindered by the presence of frozen, not still thawed sweet clover. In spring at low air temperatures the evaporation of ground moisture is insignificant, and rain deposits create additional moistening.

During the period of autumnal bad road conditions the soil is overmoistened because of the precipitation (rains, wet snow) and weak evaporation at the lowered positive air temperature. The thickness of the layer of the overmoistened soil in autumn usually does not exceed 10-15 cm. Summer bad road conditions are possible only during the period of lingering rains and are brief in view of the considerable evaporation of moisture at elevated air temperatures.

For decrease in the soaking of soil when designing the GLP it is necessary:

a) to select sections without lowered places, being well ventilated, without closely located water and vadose water (closer than 1.5-2.0 m to the surface in spring and autumn);

b) to impart increased slopes of the GLP surface for the rapid runoff of precipitation. The longitudinal slope should be not less than 0.005, and cross within from 0.05 to 0.025;

c) during the period of construction and in the process of operation to pack the soil on the entire effective area of the GLP to a depth  $1/3-1/4$  of the freezing depth. The degree of compaction of soil  $K_{y_{nn}}$  should be  $\geq 0.95$ . For the compaction of soil use heavy rollers with regulated pressure in the tires;

d) to accomplish drainage of soils and accelerated water drain on the flying field - high ditches for protection from the flow of rain and thaw water from the catchments, adjacent to the flying field; thalweg pits and sometimes dryers for the removal of water from the low sections of the GLP relief; shielding turf for the removal of flow of ground water;

e) to provide for the creation of sod covering of perennial grass mixtures taking into account the climatic and soil conditions of the area of construction of the airfield; in the process of operation provide care of the sod covering (fertilizing, sowing, moving, etc.).

The low cohesiveness and low mechanical strength of the local soil, as the building material, also affect the requirements for the geometric forms of the general relief and allowances for the quality of the relief of the GLP surface (including micro-relief). During the construction of unsurfaced flying strips it is not possible to create a surface in the form of a combination of geometrically precise and even planes, as is provided for RW with artificial coverings.

The surface of the GLP is a combination of curvilinear (smooth) surfaces with generating radius of curvature several kilometers at every point. During the construction of GLP with the aid of a complex of excavating, levelling and packing machines assigned in the project the plane is obtained in the form of a rippled surface, deviating from the projected in some direction. These deviations at intervals between points from 5 to 20 m (local relief) during the construction of GLP are allowed correspondingly from 10 to 20 cm (for RW these allowances are below); protuberances (indentations) of the microrelief of GLP under 3-5 m rods are allowed in 5 cm (for RW, the gaps under the rod are considerably less).

In the process of operation the evenness of the GLP deteriorates. The operational allowances for the quality of the local relief of GLP are 1.5-2 times greater than the constructions indicated above. The unevenness of the GLP surface in conjunction with dissimilar deformability of the soil under the aircraft wheels during takeoffs and landings create dynamic loads on the structure and equipment of aircraft. The service life of the aircraft structure during systematic flights from GLP is lowered in comparison with the flight conditions from RW, which have solid artificial coverings. The degree of reduction in the service life depends on the characteristics of the shock-absorbing systems of the aircraft landing gear.

The expounded features of dirt flying strips make them unsuitable to provide for routine and intensive flights of modern long-range and high-speed transport planes of civil aviation.

The GLP as spare strips under specific conditions can provide only single takeoffs and landings of these types of aircraft. For regular flights with low intensity of aircraft, servicing local air lines, there are set up so-called improved dirt flying strips, which are described below.

The strength of the soil of flying strips, as was noted, is changed during a year under the effect of atmospheric conditions. Therefore it must be known whether the strength of soils of flying strips is sufficient in a given period for takeoffs and landings of a specific aircraft of civil aviation.

By strength of the soil we mean the limit of plastic resistance with deformation of soil by a local load. This value is designated  $\sigma$  (in  $\text{kgf/cm}^2$ ). The required strength of soil depends on the dimensions, location and load factor of the wheels of the main struts of an aircraft, and also the reserve thrust of its engines and can be considered as the greatest for two cases:

1) the possibility of moving the aircraft from its place to the takeoff with the aid of the thrust of its engines

$$\sigma_{\text{стр}} = 1,4 \frac{g_{\text{гк}}}{m \bar{R}_0}; \quad (1)$$

2) limitation of the deformations of the flying strip surface by the maximum permissible depth of the track after the first pass of the aircraft ( $H_{\text{доп}} \leq 0.065D$  ( $D$  - outer diameter of the tires of the wheels))

$$\sigma_n = g_{\text{гк}} \sqrt{\frac{D k_{\text{танд}}}{(H)_{\text{доп}} m}} \cong 4 g_{\text{гк}} \sqrt{\frac{k_{\text{танд}}}{m}}, \quad (2)$$

where  $g_{\text{гк}} = P_{\text{к}}/DB$  - the specific load factor of the wheels of the main struts of the aircraft;

$P_{\text{к}}$  - load of main strut wheels, kg;

$D$  and  $B$  - outer diameter and width of the wheel tires, cm;

$\bar{R}_0 = R_0/G_{\text{вз}}$  - thrust-weight ratio of the aircraft;

$R_0$  - thrust at takeoff (takeoff conditions), kgf;

$G_{\text{вз}}$  - takeoff weight of the aircraft, kg;

$m$  and  $k_{\text{танд}}$  - coefficients considering the deformation of tires with rolling and repeated passage along one track of the wheels of a four-wheeled strut of an aircraft are determined from Table 10. For single and dual wheels on one axle of main struts  $k_{\text{танд}} = 1$ .

Table 10.

$\sigma$ , kgf/cm <sup>2</sup>	m	$k_{\text{танн}}$
3	1.0	1.65
5	1.1	1.65
7	1.2	1.54
9	1.4	1.54
11	1.7	1.54

Comparison of soil strength, obtained by calculation using formulas (1) and (2), with actual, determined by tests on the flying field (see § 68 Chapter XVI), will permit solving the question of the use of GLP for takeoff and landing of this aircraft.

Dirt flying strips on the fields of collective and state farms for the aircraft of agricultural aviation have some distinctive feature.

The aircraft of agricultural aviation of the An-2 and An-2M type possess good passability along the soil (required soil strength for takeoffs and landings maximum with takeoff weight is  $\sigma = 4$  kgf/cm<sup>2</sup> and more). But practice showed that for timely spring agrochemical treatment of fields the passability of these machines on poorly prepared areas of collective and state farms proves to be insufficient. A feature of this type of operation consists in the fact that it is necessary to apply mineral fertilizers to fields in very constricted periods: from the moment of complete withdrawal of the snow cover to the beginning of drying out of the soil on the fields. This period lasts from 4 to 10 days. Poorly packed and laid out areas on loamy soils (meadows, pasture, etc.) during this period have strength about 2 kgf/cm<sup>2</sup>. If we perform work from frozen soil before the removal of the snow-cover - melted water washes away fertilizer; if later, when the soil has dried, the fertilizers are not fully

mastered and their effectiveness is small. In either case the productivity is lowered, agriculture will bear losses. In this case it is necessary to keep in mind that in the economies, as a rule, the necessary construction technology is absent for the timely qualitative preparation of improved dirt flying strips.

Experience of the combined operation of aviation units of agricultural aviation and airfield construction specialists of the MGA permitted drawing up the minimum requirements for the selection and preparation of sites on the fields of state and collective farms of a number of regions of the country, with the observance of which there is ensured soil strength not less than  $4 \text{ kgf/cm}^2$  and operation of An-2 aircraft in the spring bad road condition period: 1) the dimensions and slopes of the sites should correspond to class F airfields; 2) the sites must be selected on sand-loam or light loamy soils, located on elevated and watershed sections with southern or southeastern layout and with the absence of ground waters closer than 2.5 m from the surface; 3) timely (from the autumn) in bad road conditions on the flying field (site) separate the takeoff point with width 25-30 m over the entire length of the GLP for takeoffs and landings, on which to create the increased side slopes (0.015-0.020), thoroughly lay out the surface and pack the soil in 5-8 passes of smooth metal PRK-4 rollers or pneumatic-rubber D-219 rollers (or other types) with moistness of the soil close to optimum, in the low places set up the simplest dryers (with pipes or without pipes, but with a filling trench with crushed stone or gravel); 4) before intense snow melting (one-two weeks) thoroughly clean the site of snow (in winter do not remove snow from the site), after snow removal for accelerating the thawing of soil cover the surface with a thin layer of ashes, coal or peat dust, slag; 5) in the intervals between flights level the wheel tracks with light rollers.

Radical improvement of the operational conditions of aircraft on airfield dirt strips can be achieved only by the construction of lightened type coverings. Some reduction of the duration of the nonflying period can be achieved, having created a good sod cover and having improved the planning of airfields, particularly, having eliminated all places where water can stand. The bad road condition period can be shortened with the aid of several operational measures, described below.

#### § 6. SOD COVER

Sod cover is the top layer of soil, densely overgrown and secured with roots of perennial grasses. This increases the supporting capacity of the ground, decreases its ability to become sodden, dust formation at the airfield, and contributes to shortening of the period of the spring bad road conditions. The sod cover on the LP should withstand a load from aircraft wheels with internal tire pressure  $5-7 \text{ kgf/cm}^2$  without the formation of wheel tracks deeper than 3-5 cm, possess as much as possible a uniform structure and density of the soil on the entire working area of the field, have an even and thick grass stand.

The quality of the sod cover is determined by its thickness, coherence and state of the grass stand. Depending upon the thickness the turf is subdivided into the following types: slight - with thickness of sod layer up to 6 cm; medium - from 6 to 11 cm; thick - thickness exceeds 11 cm. The sod cover on airfields should have layer thickness not less than 6-7 cm.

With respect to coherence we distinguish the following types of turf: slightly cohesive - easily broken up with the hands, or easily cut up; medium cohesive - cut up by a spade with difficulty and requires effort for breaking up with the hands; highly cohesive - does not lend itself to breaking up with the hands and is cut up by a spade or hoe with great difficulty. The turf



possesses satisfactory quality when a sample of it 12-15 cm thick and 6 × 15 cm in area, cut out in moist state, is not broken down and is not torn off with its careful lifting from the grass.

The grass stand is the surface part of the layer: it should be thick, uniformly close, not above 20-30 cm. The quality of the sod cover depending on the state of the grass stand is determined by the quantity of shoots per unit of area (Table 11).

Table 11.

Turf	Quantity of shoots per 20 × × 20 cm area		
	sod- podzolic and forest- steppe zone	chernozem zone	dry steppes and semi- desert
Poor.....	<100	<50	<35
Satisfactory....	100-200	50-100	35-50
Good.....	200-400	100-200	50-100
Excellent.....	>400	>200	>100

At airfields utilized by aircraft with jet engines the turf should be stable and be rapidly restored after scorching by the jets of hot gases from the engine nozzles. For increasing the resistance of the sod cover to burnout a special selection of grass-ground cover is made.

The best grasses - sod-formers are meadow grasses with admixture (up to 25%) of legumes, which together create a thick system of roots and rhizomes, densely penetrating the top layer of the soil (grass) and connecting it with the underlayers (legumes). With respect to resistance to abrasion and wear the most stable is pasture rye grass, the most resistant to high temperatures is awnless brome grass, the best ground cover with respect to all the criteria is blue grass.

The strength of the sod cover depends on the qualitative composition of the surface layer of the soil of the flying field, the features of grasses and sod-formers, humidity, temperature, care and others. The top plant layer of the earth should be well penetrable for water and air, sufficiently cohesive and at the same time elastic.

The best soils for the creation of durable sod cover - highly fertile sandy-loam and light loamy, which have durable crumbly structure. The humus content in the soil should not exceed 4-8%, since humus, as clay, sharply lowers the water permeability of the soil. A flying field with increased humus content has reduced supporting power of the surface covering. The reaction of the soil should be weakly acid or weakly alkaline. To avoid the premature dying of grasses it is necessary to strictly observe the conditions of operation of the sod covering on unpaved airfields.

## CHAPTER IV

### DRAINAGE OF THE FLYING FIELD

#### § 7. PURPOSE OF THE DRAINAGE SYSTEM

The operation of flying fields is permissible if the soils possess high supporting power, which depends on their moisture content. With considerable moisture content the load-bearing capacity of soil is sharply lowered and the normal operation of aircraft from ground takeoffs becomes impossible. For the favorable development of sod cover on the flying field the soils also should not be too moist. Thus, on unsurfaced takeoff strips of flying fields excess moistening is inadmissible. Therefore the main task of the drainage system of the flying field is the removal of the excess surface or ground water. During the construction of the drainage system of the flying field it is necessary to consider the reasons for excess moistening and the types of water supply. The excessively moistened areas of the flying field proceeding from conditions which cause overmoistening of the soil, in the assumption of Prof. A. V. Brudastov, are divided into four main types:

a) areas of alluvial feed, which are characterized by overmoistening of the surface by the inflow of water from sections

located outside the flying field, and also by flooding of the territory during seasonal floods;

b) areas of atmospheric feed, which are characterized by bogging due to overmoistening by precipitation and by thaw water. The overmoistening of such areas is characteristic for sections with small slopes, complex microrelief and slight water permeability of the cover rocks (clays, heavy and medium loams, heavy and medium dusty sandy loams);

c) areas of ground feed, which are characterized by overmoistening of the surface as a result of the capillary rise of ground moisture, and also as a result of vadose water from precipitation. Such type of overmoistening is characteristic for sections with layers of small thickness of the soils being penetrated (sands, sandy loams and light loams), underlain by water-repellent soils (clays or heavy loams);

d) areas of ground-delivered feed, which are characterized by excess moistening as a result of the squeezing out of forced ground waters to the surface of the flying field or their capillary rise. This type of overmoistening is encountered in the terrace parts of fluvial valleys with the presence of loose rocks, covered by a layer of clay or loam.

The described types of water feed can be encountered both individually and in combination with each other. Drainage systems considerably accelerate the drying out of soils at the sites and reduce the periods of bad road conditions at the airfields.

## § 8 THE PRINCIPLES OF DRAINAGE

The drainage of the flying field should be solved taking into account the project of the vertical planning of the airfield.

In a number of cases the vertical planning can largely eliminate the excess overmoistening of the soil. While creating the project of vertical planning of the flying field it is necessary, as a rule, to ensure the natural runoff of surface water.

The methods of drainage of the flying field depend on the causes of the formation of excess overmoistening and the type of water feed.

Protection from the inflow of water, running off from adjacent catchment areas, is accomplished with the aid of high ditches, which intercept and discharge water into the nearest basins or into depressions in the relief. The earth banks of high ditches should be set up on the side of the airfield continuous for the entire length. For interception and diversion of water there can be used embankments and side drains of automobile roads and railroads, passing near the airport. For protection of the flying field of the airfield from flooding during seasonal floods dikes with reinforced slopes are constructed. The height of such dikes is taken 0.5 m higher than the highest horizon of flood waters, which is repeated once in 10 years.

With atmospheric feed the main method of drainage of the flying field is the acceleration of runoff for the purpose of rapid water removal outside the airfield and maximum decrease in the absorption of precipitation by soils. For the prevention of standing water in this case there is set up a special storm sewer system. With ground feed there is provided lowering of the level of ground water with the aid of drains. The draining standard (maximum permissible depth from the soil surface to the maximum level of ground water or prolonged perched water table) for GLP is taken equal to 0.6 m in sandy and sandy-loam soils and 0.8 m in loamy. With ground-delivered feed at the points of water emergence to the surface it is intercepted by trap channels or by closed

collectors; in a number of cases drainage is set up. As a rule, water removal from the drainage network should be accomplished by gravity. The construction of pumping plants which require constant maintenance is allowed only in exceptional cases with special substantiation.

When selecting the type of drainage of the flying field one must take into account the climatic zones of the USSR, geological and hydrogeological conditions, area relief.

#### § 9. SCHEMES OF DRAINAGE AND SEWER SYSTEMS

The project of construction of the drainage system is developed taking into account the type of water feed of the area, character of the relief and surface of the flying field. The area relief is exposed with the aid of detailed geodetic photography of the planned surface, as a result of which we more precisely determine the presence and location of low areas.

The drainage system of the flying field consists of closed elements of the network (dryers, drains, collectors, sewers, trap drains) and open elements - channels, the construction of which is admissible only outside the outer edges of the approach corridor. The dryers are set up for the removal of the surface water with atmospheric feed, and drains - for removal and lowering of ground waters with ground and ground-delivered feed. The collectors receive and drain off the water flowing out of dryers or drains.

The sewers drain off the water entering from collectors. Trap drains are set up with ground and ground-delivered feed and are intended for the interception of ground waters from an external water intake.

The open include discharge, high and trap channels. The discharge channels remove water from the closed drainage network into a water intake. High channels are intended for the capture of water which enters from adjacent spillways. The trap channels capture and drain off water with ground and ground-delivered feed.

The drainage network with atmospheric feed is set up as selective (Fig. 6), intended for drainage of separate sections

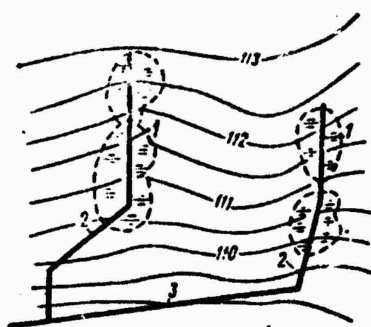


Fig. 6. Diagram of selective drainage of separate low places: 1 - dryer; 2 - collector; 3 - sewer.

of the flying field, and as constant (Fig. 7), with which drainage is accomplished on the entire flying field.

During selective drainage with a small quantity of overmoistened sections sewer drains are marked out in a plane along low sections and along thalwegs, where there can primarily be the accumulation of precipitation and overmoistening of soils. With constant drainage of the swampy sections drainage lines are marked

out at an acute angle to the surface

horizontal in the form of parallel lines, which ensure the best water catchment. The distances between sewer drains are usually taken on the basis of test work and are tentatively given in Table 12. The angle between the dryers and collectors being coupled in the direction of motion of water is taken from 75 to 90°.

Fig. 7. Diagram of constant drainage of the flying field: 1 - dryer; 2 - collector; 3 - sewer; 4 - main sewer.

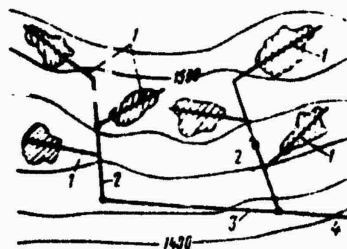


Table 12.

Soils	Surface slopes									
	0.001	0.002	0.003	0.004	0.005	0.006	0.007	0.008	0.009	0.01
	Distance between dryers, m									
Clay.....	25	35	40	45	50	55	60	65	70	75
Medium loam.....	35	45	50	55	60	65	70	75	80	85
Heavy dusty sandy loam..	45	55	60	65	70	75	80	85	90	95

Collectors as much as possible should be marked out perpendicular to the surface horizontals of the flying field. With two-sided joining of the sewer drains the distance between collectors is taken as double the length of dryers, while with single - a single length of the dryers.

The coupling of pipes of the sewer drains with the collector pipes is usually accomplished with the aid of shaped stones (Fig. 8), and with the absence of such stones the pipes of the dryer are put into the collector pipes.

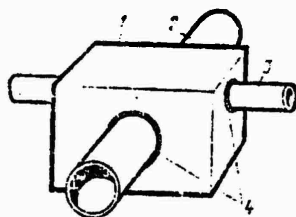


Fig. 8. Coupling of pipes of sewer drains with collector pipes: 1 - shaped stone; 2 - collector pipes; 3 - dryer pipes; 4 - tar-impregnated hemp 1-1.5 cm.

Sewers and main channels are laid along the shortest path to water intakes, by arranging them in the low places of the surface of the flying field. The maximum permissible length of the elements of the sewer drainage network is taken according to Table 13. In a number of cases the surface water can be concentrated in the closed low places of the dirt part of the flying strip, and also in the places between the RW, RD and MS.



For the removal of surface water from such places we set up thalweg wells with water discharge from them into sewers, draining off the water away from the airfield. The slopes of the elements of the drainage network on the flying field are designated so as to eliminate their erosion and clogging (Table 14).

Table 13.

Element of drainage network	Maximum length of elements, m	
	Normal	In exceptional cases
Main sewer and sewers.....	1000	1500
Collectors.....	200	250
Sewer drains with pipes	100	150
Sewer drains without pipes	50	65

Table 14.

Element of drainage network	Standard slopes of elements of the sewer drainage network	
	minimum	maximum
Main, high and trap channels.....	0.0005	0.006
Main sewers and collectors with pipes more than 30 cm in diameter.....	0.0010	0.008
Main sewers and collectors with pipes up to 30 cm in diameter.....	0.0015	0.010
Collectors and drains with pipes	0.0020	0.010

The depth of laying of the pipe dryers must be taken as small as possible. It is established on the basis of the strength calculation of pipes from the effect of an aircraft load. For airfields with given wheel load 17 and 12 t the minimum depth of laying for clay and asbestos-cement pipes 50-75 mm in diameter is taken not less than 0.60 m. With ground and ground-delivered feed on the air field is set up a sewer network, with the aid of which water is discharged and the level of ground water is lowered to the established norm of drainage. The low surface of the ground waters in this case in the transverse direction is characterized by a depression curve (Fig. 9). The level of action of the sewer is the level, below which the sewers cannot lower the ground water.

We distinguish two types of drainage: perfect, at which the drains pour directly into a water-confining stratum, and imperfect, at which the drains pour above the water-confining stratum. The drainage network in the plan is arranged similar to the arrangement of sewer drainage network and includes drains, collectors and sewers. At the flying field is laid constant drainage or selective in separate sections with high level of ground water. Drainage sewers, as a rule, are arranged perpendicular to the motion of the ground water, parallel to the water table contour (Fig. 10).



Fig. 9. Diagram of lowering of the level of ground water by the drainage network: 1 - actual water level; 2 - depression curve; H - minimum laying depth of the ground water.

The distances between drains are designated depending on the soil:

Meager clay.....	8-10 m
Heavy sand loam.....	10-12 m

Medium loam.....	12-14 m
Light loam.....	14-16 m
Dusty loam.....	16-18 m
Medium-grained sand.....	17-20 m

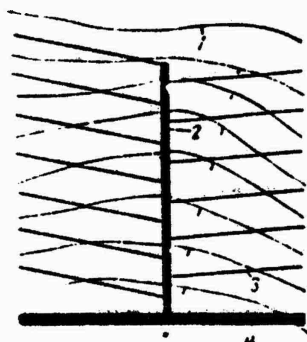


Fig. 10. Diagram of the filling of the sewer drainage network: 1 - water table contour; 2 - collector; 3 - drains; 4 - sewer.

The depth of laying of drains depends on the hydrogeological conditions of the terrain and it is established by calculation. For preventing the breakage of pipes it is recommended to lay pipe drainage lower than the freezing depth of the soil. Usually the drainage network on the flying field is laid to a depth from 1.0 to 1.5 m, in this case the depth of laying of drains should be somewhat more than the required norm of drainage.

The laying depth of the collectors, sewers and main channels is determined by the form of their coupling with drains. Trap drains with ground-delivered feed are laid from the top of the swampy section. With fine bedding of water-confining stratum the trap drains are set up on the water-confining stratum or close to it. With depth of occurrence of water-confining stratum 2.5-3.0 m the trap drain is set up less than this depth.

The slopes of the drainage network and the permissible speeds of water in them depend on the construction features of the drains. The maximum slopes of drains from clay pipes are given in Table 15. The calculated speed of motion of water in drains should not allow either the clogging of pipes or the erosion of

soil at the places of location of joints. For clay, concrete and wooden drains the speed of water is allowed from 0.25 to 1 m/s.

Table 15.

Diameter of pipe, cm	Maximum slopes		Diameter of pipe, cm	Maximum slopes	
	maximum	minimum		maximum	minimum
4.0	0.080	0.0032	10.0	0.024	0.0009
5.0	0.056	0.0023	13.0	0.017	0.0007
6.5	0.040	0.0019	16.0	0.013	0.0005
8.0	0.035	0.0013			

## § 10. CONSTRUCTIONS OF ELEMENTS OF DRAINAGE SYSTEMS

The constructions of elements of the drainage systems of the flying field should ensure the safe operation of aircraft on airfields and satisfy the requirements for maximum prefabrication and industrial feature of construction. When building the drainage network at airfields we use the following constructions: a) sewer pipe drains; b) pipe drains; c) collectors and sewers; d) drain constructions.

Sewer drains (Fig. 11) made of clay or asbestos-cement pipes 50-75 mm in diameter are laid in rectangular type trenches with width along the bottom 0.1-0.2 m, and weak soils - trapezoidal type with width along the bottom 0.20 m larger than the pipe diameter. Before laying the pipes we set up the base from packed crushed stone or gravel. In asbestos-cement pipes for the reception of water along the entire length of the drain every 0.3-0.5 m we make grooves 1-1.5 mm wide to a depth  $\frac{2}{3}$  of the diameter of the pipe. The clay pipes are laid without framing of joints. The trenches are filled in by the filter method, with which materials of larger fractions are arranged in the underpart with gradual decrease in the value of fractions at the top of the trench. As the filtering materials we use sand-gravel mixture, large crushed stone or gravel of fractions 3-5 cm. The use of large pebbles 5-10 cm in size is possible also. However in this case above the filling there is additionally laid a layer of gravel 5 cm thick.

At the top of the trench there is left a water-receiving slot, the remaining part of the sewer drain is treated with hot asphalt by the impregnation method with asphalt consumption 6-7 l per 1 m<sup>2</sup> or it is sodded.

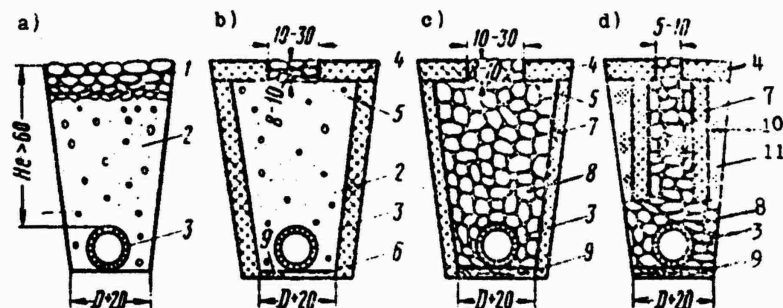


Fig. 11. The construction of sewer drains: a) gravel receiving part; b) receiving part in the form of a narrow slot with sand-gravel mixture filling; c) the same, with sifted gravel filling; d) the same, with limited width of gravel filler; 1 - gravel filling (top layer 5-6 cm, bottom 2-3 cm); 2 - sand-gravel mixture; 3 - clay or asbestos-cement pipes; 4 - sod 5-10 cm thick; 5 - layer of crushed stone (gravel) of fraction (sic) 1-3 cm, treated with asphalt; 6 - coarse-grained sand; 7 - sod 5-10 cm thick; 8 - gravel or crushed stone of fraction 5-6 cm; 9 - preparation from packed crushed stone with layer 5-7 cm; 10 - gravel or crushed stone of fraction 1-2 cm; 11 - soil.

Pipe drains made of clay, asbestos-cement and ceramic pipes 100 mm in diameter (Fig. 12) are laid in a trapezoidal trench with width along the bottom 0.20-0.25 m and with depth 1.0-1.5 m and are filled in with gravel or crushed stone. Above the filling we lay the insulating layer of sod or moss, whereupon the trench is filled with the soil, removed earlier from the trench. Over the filled in and packed soil we place a plant layer 10-15 cm thick.

Collectors and sewers made from asbestos-cement, high-strength concrete and reinforced-concrete pipes (Fig. 13) are laid in the trench, as a rule, of trapezoidal cross-section with width along the bottom 10-25 cm more than the pipe diameter. The slopes of the trench in stable soils are taken 7:1 and in less stable 4:1. Depending on the material pipes of the following diameters are taken: asbestos-cement pipes with inner diameter 75-546 mm; high-strength cement pipes with inner diameter

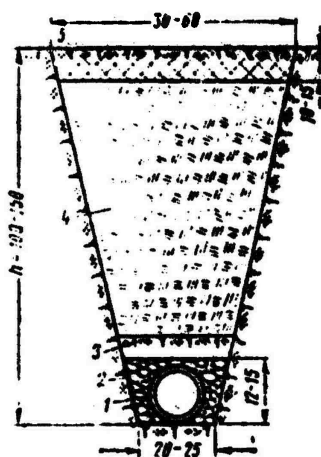


Fig. 12. Construction of drainage trench: 1 - drain pipe with diameter not less than 10 cm; 2 - stone filling; 3 - insulation with sod or moss; 4 - filling with soil, removed from the trench; 5 - vegetable soil.

300-500 mm; reinforced-concrete with inner diameter 500 mm and more. During the construction of the drainage network from pipes with diameter less than 500 mm preference should be given to the asbestos-cement pipes, which are more reliable and economical.

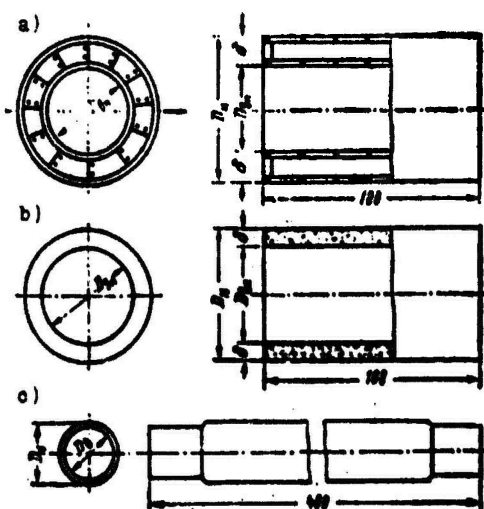


Fig. 13. The pipes of drainage systems: a) reinforced-concrete; b) concrete; c) asbestos-cement.

The pipes are laid on a planned base and are connected by couplings. The joints of couplings are poured over with asphalt or cement test. High-strength cement pipes are compulsory

tested - five pipes from each batch of 100 pieces. The pipes are considered having withstood testing if with load 1.5 times less than breaking no damage is established. Reinforced-concrete pipes are used with height of filling above the top of the pipe not less than 0.75 m. The pipes are made of concrete of a brand not below 200 with fittings from steel of class A-I, having design tensile strength  $2100 \text{ kgf/cm}^2$  or steel of class A-II of periodic shape with design strength  $2700 \text{ kgf/cm}^2$ .

The conditions of the suitability of reinforced-concrete pipes after testing are the same as for concrete. The joints of concrete and reinforced-concrete pipes should be thoroughly sealed. The joints are set up from roofing felt or ruberoid or from cement mortar. In the first case the joints overlap with two layers of roofing felt or ruberoid in the form of 150-200 mm strips on hot pitch. In the second case at the places of joining of pipes there is applied a belt of cement mortar 1:3.

The concrete and reinforced-concrete pipes of sewers are laid on the bases made in one piece or of assembled blocks. Cement pipes with diameter 300-500 mm are laid on bases made of assembled concrete blocks (Fig. 14) with strength of concrete under compression not less than  $300 \text{ kgf/cm}^2$ . Blocks are laid on a layer of cement mortar with calculation of 10-20 l per  $1 \text{ m}^2$  of the block bottom. Vibration ensures the tight fit of the blocks to the soil.

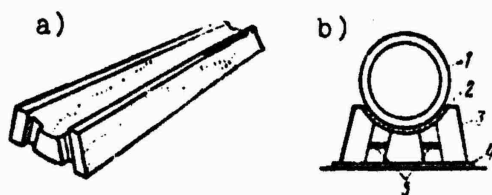


Fig. 14. Sewer pipes on a base made of assembled blocks: a) block for base under the sewer pipe; b) general view of the sewer pipe and base made from assembled blocks; 1 - sewer pipe; 2 - cement

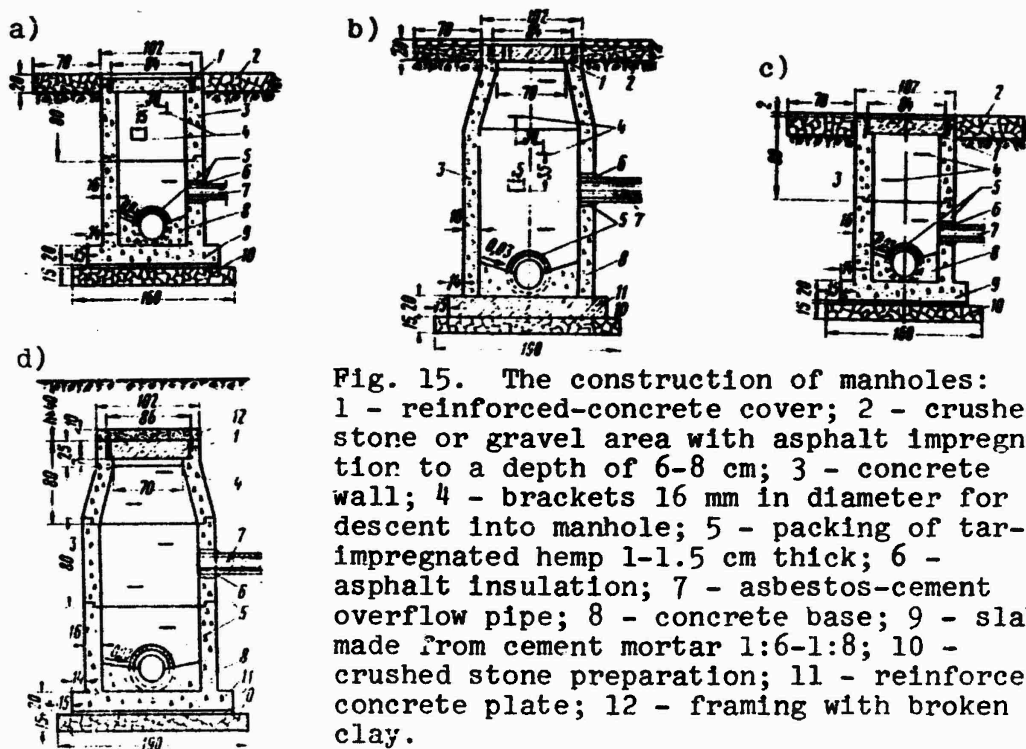
mortar 1:3 - 1:4; 3 - block of the base; 4 - cement mortar 1:6-1:8; 5 - mounting clamps 10 mm in diameter.



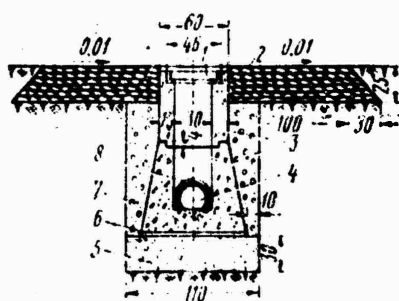
Reinforced-concrete pipes with diameter over 600 mm, when the modulus of the underlying soil is equal to or more than  $300 \text{ kgf/cm}^2$ , are laid on monolithic concrete bases, and with deformation of the soil less than  $300 \text{ kgf/cm}^2$  we set up reinforced-concrete bases. The thickness of concrete and reinforced-concrete bases is determined by calculation and is taken as 15-20 cm. Constructions on a sewer drain network consist of manholes and thalweg wells and outfall constructions.

The manholes of sewers are set up as rectangular and round from precast and in situ concrete. Rectangular wells with internal size in the plan  $0.7 \times 0.7 \text{ m}$  (Fig. 15a) are used with external diameter of sewer less than 700 mm and depth of laying of pipes not less than 2.0 m. With greater depth of laying and larger diameter of sewer pipes we use wells with internal size  $1 \times 1 \text{ m}$  (Fig. 15b). Round wells (Fig. 15c) with inner diameter 0.7 m are used with external diameter of sewer up to 400 mm and laying depth of pipes up to 2.0 m. With the external diameter of sewer 400-500 mm and greater laying depth of pipes we used round wells with inner diameter 1 m (Fig. 15d).

Manholes of two types are constructed: with covers on the surface; with buried covers. Manholes with buried covers are constructed only at the points of intersection of sewers with the effective area of the unsurfaced strip of the flying field. In all remaining cases on the flying field we construct the first type of manholes. It is advantageous to use manholes from precast reinforced-concrete elements - cover, opening of middle components and bottom. Under the bottom of the manholes is laid out a crushed stone or gravel slab 15-20 cm thick. Around the manholes with covers on the surface at a distance of 0.8-1.0 m from the edge there should be crushed stone or gravel reinforcement of the soil 20 cm thick with asphalt impregnation to a depth of 6-8 cm.



Thalweg wells (Fig. 16) are constructed of rectangular cross section with approximate dimensions in the plan  $1.6 \times 0.3$  m and  $2.4 \times 0.3$  m from precast or in situ reinforced concrete.



The lattices of thalweg wells from two-three components are metal, welded and are placed on supporting frames. The lattices of thalweg wells are located 8-10 cm lower than the surrounding ground surface and are connected with it by a funnel-shaped area.

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Table 16.

Soil or type of reinforcement	Permissible noneroding speed, m/s
Slimy ground	0.15
Fine sand	0.35
Medium	0.50
Course	0.75
Light loam	0.40
Medium	0.60
Heavy	0.80
Dense clay	1.20
Flat turfing	1.20
Turfing to the wall	1.30
Single surfacing	2.50
Double	3.50
Brickwork	3.50
Concrete facing	5.00

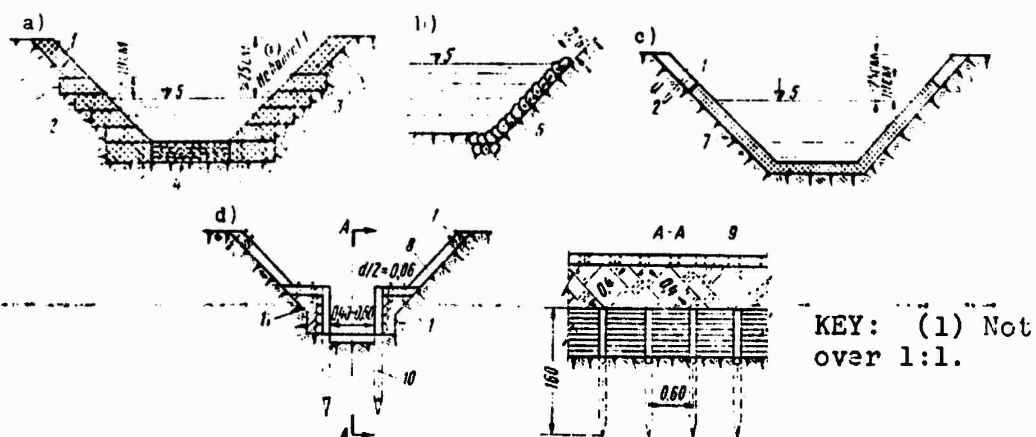


Fig. 18. Reinforcement of banks of the channels: a) sodding; b) paving; c) soil treated with organic binder; d) wooden fastening; 1 - flat sod; 2 - wooden spokes 25-30 cm long with cross section 2 x 2 cm; 3 - sod 30 x 50 cm in size, packed (with the exception of the top layer) with grass down; 4 - crushed stone with layer 5-8 cm; 5 - water level in the channel; 6 - layer of soil, treated with organic binder, moss or straw; 8 - vegetable soil; 9 - strips of sod into square; 10 - wooden posts 0.12 in diameter; 11 - dirt filling.

## § 11. PRINCIPLES OF CALCULATION OF DRAINAGE SYSTEMS AND THEIR ELEMENTS

When designing the drainage systems on airfields there are accomplished: hydraulic calculation of the drainage network, strength calculation of elements of the drainage network. Hydraulic calculation makes it possible to determine the diameters of pipes, the cross section of troughs and channels in the discharge and drainage network depending on the calculated water consumption. Strength calculation is accomplished for the purpose of determining the design loads and forces from the action of the aircraft wheels and selection of the cross sections of the elements of the drain network.

### a) Hydraulic calculation of the drainage network.

The hydraulic calculation of the drainage network is performed taking into account the degree of moistening and the type of water feed. The method of calculation is developed by Soviet scientists A. M. Kostyakov, G. A. Alekseyev, L. T. Abramov, N. I. Belov, P. F. Gorbachev and others. With the atmospheric type of feed the calculated consumptions of drainage lines are determined by the method of limiting intensities with determination of the calculated rain force  $\Delta$  and with consideration of the maximum time of drainage formation  $T_{np}$ . Basic prerequisites of this method are the following.

The calculated rain force  $\Delta$ , which characterizes its relative intensity, is determined by the formula of the State hydrological institute (proposed by G. A. Alekseyev)

$$\Delta = A + B \lg N, \quad (3)$$

where A and B - constant parameters characterize the downpour nature of rains, the physicogeographical and climatic conditions of the region of construction

of the airfield and are taken according to climatic handbooks;

N - period of single overfilling of the drain network being taken; not less than 0.2 year for an arid zone and zone of insufficient moistening; 0.3 year for zone of variable and excess moistening; 0.5 year for zone of excess moistening with average annual amount of precipitation more than 500 mm.

The characteristic of the climatic zones of the USSR and their geographic boundaries are given in Table 17 and on the map of Fig. 19.

The maximum time of drainage formation, i.e., the duration of the rain, during which the precipitation forms surface runoff  $T_{np}$ , is determined by the formula

$$T_{np} = K \left( \frac{\Delta}{i_{cr}} \right)^{1.5} \text{ min}, \quad (4)$$

where K - the coefficient which considers the duration of runoff after the termination of rain, taken equal to 2.0 for the arid and insufficient moistening zones; 1.75 for the zone of variable moistening; 1.50 for the zone of excess moistening

$i_{cr}$  - limiting mean drainage-forming rainfall intensity, established by L. T. Abramov for concrete coverings 0.30 mm/min.

After determination of  $\Delta$  and  $T_{np}$  there is performed hydraulic calculation of the drain networks of the flying field and the artificial coverings on the basis of L. T. Abramov's nomograms in the following sequence:

a) determine the dimensions of catchment area F, length of catchment L and side slope 1. By the length of catchment L and surface slope 1 for rain force  $\Delta = 3$  and roughness factor

Table 17.

No. of zone	Characteristic of zone	Geographic boundaries of the zone
I	Permafrost zone	Includes the zone of tundra, forest-tundra and the north-eastern part of the forest zone. Is located to the north of the line: Monchegorsk - Ponoy - Nes'-Oshkur'ya - Suxaya - Kansk - state boundary - Birobidzhan - De-Kastri.
II	Excess moistening zone	To the south of boundaries of I zone includes the zone of forests to the line: L'vov - Zhitomir - Kaluga - Gor'kiy - Izhevsk - Tobol'sk - Tomsk - Kamsk and further to the south of I zone to boundaries with the Peoples' Republic of China.
III	Variable moistening zone	Includes the forest-steppe zone to the south of II zone to the line: Kishinev - Kirovograd - Khar'kov - Kuybyshev - Chkalov - Omsk - Biysk.
IV	Insufficient moistening zone	To the south of boundaries of III to boundaries of the V zone includes the steppe zone.
V	Arid zone	To the south and east of the line Dzhul'fa - Stepanakert - Kirovabad - Kizlyar - Sal'sk - Volgograd - Ural'sk - Aktyubnisk - Turchat - Karaganda - Semipalatinsk includes desert-steppe and desert zones with the propagation of saline soils.

Note. The climatic conditions for mountain regions are determined in each individual case from local weather data.

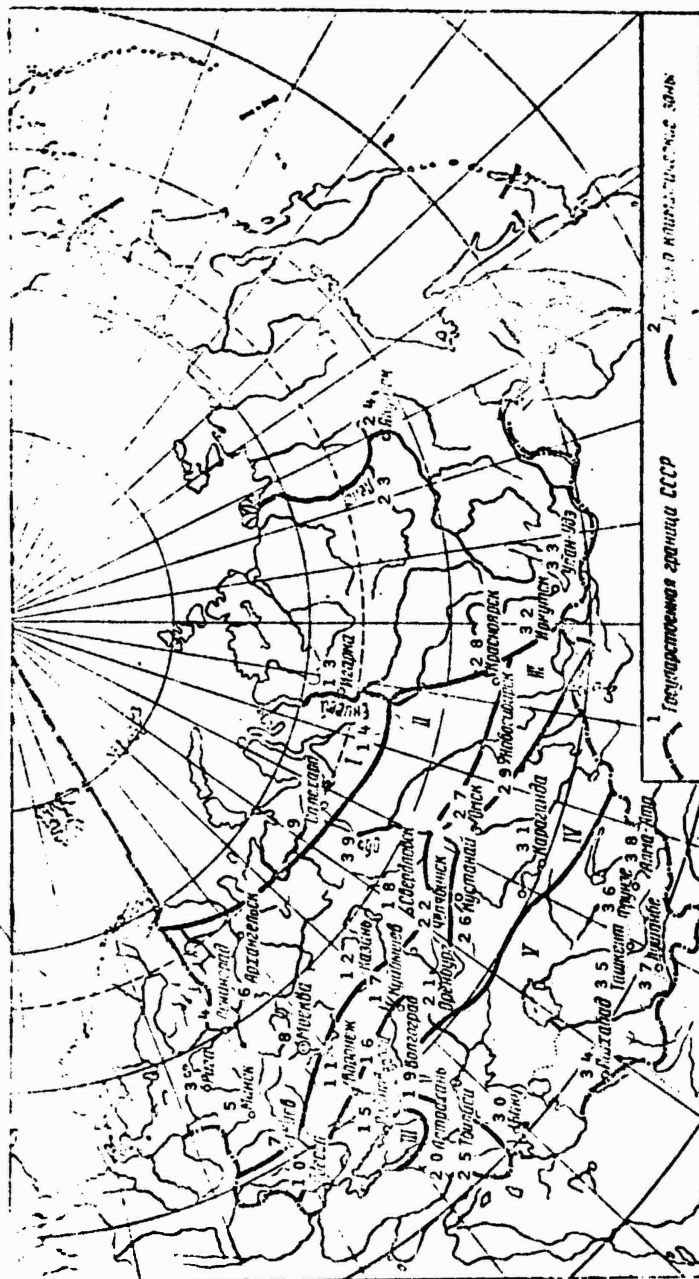


Fig. 19. Map of the climatic zones of the Soviet Union.  
 KEY: 1 - National boundary of the USSR; 2 - Road and climate zones; 3 - Riga; 4 - Leningrad; 5 - Minsk; 6 - Arkhangel'sk; 7 - Kiev; 8 - Moscow; 9 - Salekhard; 10 - Odessa; 11 - Voronezh; 12 - Kazan'; 13 - Igarka; 14 - Yenisey; 15 - Rostov; 16 - Volga; 17 - Kuybyshev; 18 - Sverdlovsk; 19 - Volgograd; 20 - Astrakhan'; 21 - Orenburg; 22 - Chelyabinsk; 23 - Lena; 24 - Yakutsk; 25 - Tbilisi; 26 - Kustanay; 27 - Omsk; 28 - Krasnoyarsk; 29 - Novosibirsk; 30 - Baku; 31 - Karaganda; 32 - Irkutsk; 33 - Ulan Ude; 34 - Ashkhabad; 35 - Tashkent; 36 - Frunze; 37 - Dushanbe; 38 - Alma Ata; 39 Ob'.



$C = 0.160$  by nomogram (Fig. 20) there is determined the running time of rainwater along the catchment  $t_0$  min. For obtaining the running time of rainwater for other values of  $\Delta$  and  $C$  one should multiply  $t_0$  by nomogram values of the correction factors  $\phi$  (by rain force) and  $\psi$  (by surface roughness), i.e.,  $t_1 = t_0 \phi \psi$  min;

b) calculate the running time of water to the calculated section by formula

$$t_2 = \frac{l}{v_{cp}} \text{ min}, \quad (5)$$

where  $l$  - length of the calculated section, m;

$v_{cp}$  - average speed of water flow, m/min;

c) determine the calculated running time to the first calculated section

$$T_1 = t_1 + t_2 \text{ min}; \quad (6)$$

d) by the calculated running time  $T_1$  and rain force  $\Delta$  with coefficient of cover  $z = 0.237$  (for concrete surface) according to the nomogram given on Fig. 21, determine the modulus of runoff (unit calculated flow rate)  $S_1$  (in l/s) from 1 ha of catchment.

The modulus of runoff for other values  $z_i$  are determined by formula

$$S_i = S_1 = \frac{z_i}{0.237}; \quad (7)$$

e) determine the calculated flow rate for the first section of the network by formula

$$Q_1 = S_1 F_1 \text{ l/s}; \quad (8)$$

f) select the diameter of pipe  $D$  by the value of  $Q_1$  and slope of pipeline.

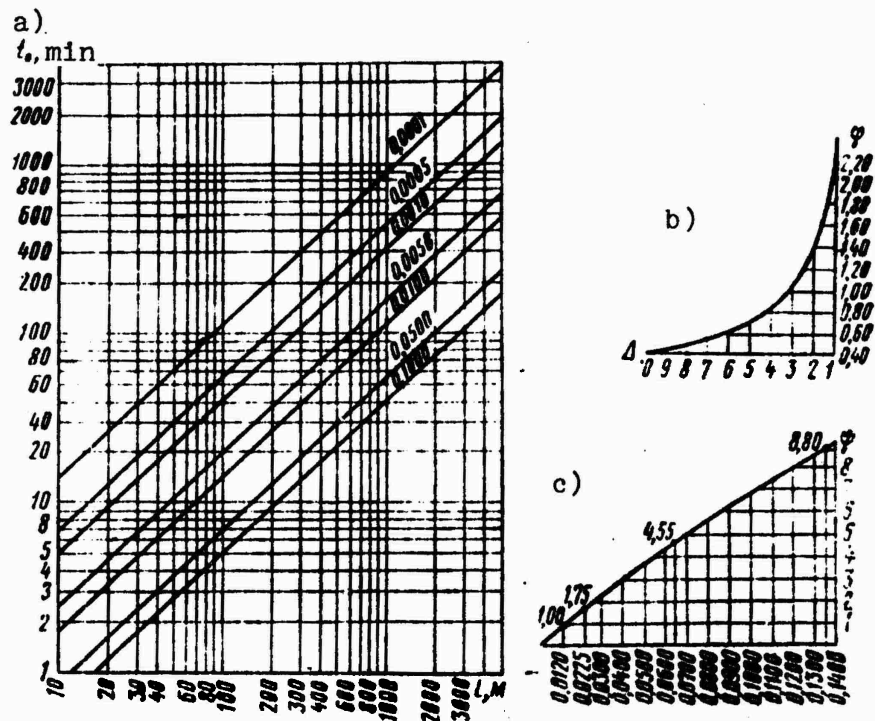


Fig. 20. Nomogram for determining the periods of running of rainwater: a) basic nomogram; b) nomogram of correction factors  $\phi$  for rain force; c) nomogram of correction factors  $\psi$  for the roughness factor.

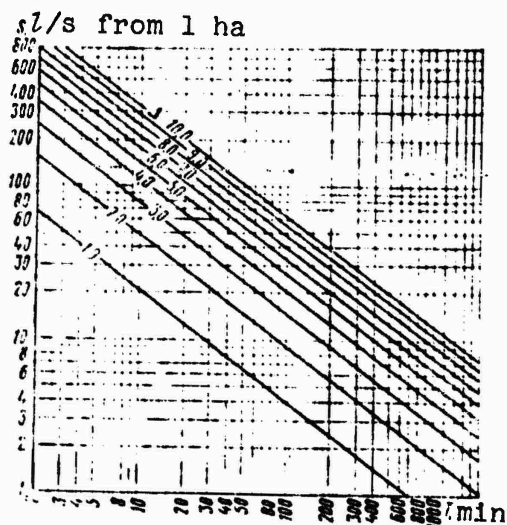


Fig. 21. Nomogram for determining the modulus of runoff (in  $l/s$ ) from 1 ha.

The subsequent sections of drain lines are calculated analogously to the first, in this case to the calculated running time it is necessary to add the running time of water along the previous section of the pipeline

$$T_2 = T_1 + \frac{l_n}{v_n} \quad (9)$$

where  $l_n$  - length of the previous section, m;

$v_n$  - average speed of water flow in pipes on the previous section m/min.

We further determine the modulus of runoff  $S_2$ , calculated flow rate  $Q_2$  and select the sections of pipes. The subsequent calculations are performed in the same order. During the calculation of drains of artificial coverings the calculation is performed also before obtaining the running time, equal to the maximum time of drainage formation  $T_{np}$ . By the maximum time of drainage formation there is determined the calculated flow rate, which for the next sections of the sewer is taken constant.

The diameter of pipe drains should be taken constructively (without calculation); the diameter of pipes is taken not less than 10 cm.

With ground type of feed by calculation there is determined the distance between drains  $A$ , the flow rate of water entering the drain  $Q$ , and the working time of drainage for lowering the level of ground water to the accepted norm of drainage. The distance between drains (m) is determined by formulas:

for perfect drainage

$$A = 2 \sqrt{\frac{k}{p} [(H - S)^2 - h_0^2]} \quad (10)$$

for imperfect drainage

$$A = \frac{2(H - S) \pm k}{l_n \left( \frac{A}{d} \right) p} \quad (11)$$

where  $k$  - filtration factor, m/day;  
 $p$  - seepage factor, m/day;  
 $H$  - thickness of water-bearing layer, m;  
 $S$  - norm of lowering of the ground water level, m;  
 $h_0$  - height of water level in the drain, m;  
 $d$  - diameter of drain, m.

The flow rate of water entering the drain is determined by formula

$$Q = pAl \text{ m}^3/\text{s} \quad (12)$$

where  $l$  - length of drain, m. The working time of drainage for lowering the level of ground water  $T$  to the accepted norm of drainage is determined by formula

$$T = \frac{Q}{g} \text{ days} \quad (13)$$

where  $g$  - discharge capacity of the drain with accepted diameter  $d$ .

The lowering time of the level of ground water for airfields should be taken as not more than two-three days. Hydraulic calculation of the drains is not performed. Their diameter is taken from conditions of the nonsilting of pipes within 75-100 mm.

With ground-delivered feed the calculated flow rate of runoff is established on the basis of detailed research on the particular hydrogeology of the section. The open collecting channels, which receive water from the sewers, should be designed for flow rates which correspond to the discharge capacity of the sewers.

High ditches are usually not calculated. If necessary it is possible to calculate them by the methods applied in land reclamation.

The hydraulic calculation of closed sewers is performed by the Chezy formula with their complete filling.

The analysis of drainage measures shows that the calculated case, as a rule, is the removal of precipitation. However, for airfields located in the excess moistening zone, the section of sewers should also be checked for the admission of thaw water. In this case the calculated flow rates are determined by formulas:

- a) with catchment areas up to 5 km<sup>2</sup>

$$Q_0 = \frac{0.278 AF}{\sqrt{F+1}} \phi \text{ m}^3/\text{s}, \quad (14)$$

where A - value of elementary runoff, mm/h;

F - catchment area, km<sup>2</sup>;

$\phi$  - runoff coefficient, taken equal to 0.80-0.95;

- b) with catchment areas over 5 km<sup>2</sup>.

$$Q_0 = \frac{0.278 AF}{\sqrt{F}} \phi \text{ m}^3/\text{s}. \quad (15)$$

- b) Strength calculation of elements of drainage network.

The pipes of the drainage network are calculated for load from wheels of the calculated aircraft and from the weight of the soil above the pipe by the method of limiting conditions. When determining the load from wheels there are considered the conditions of its transfer through the filling soil. For this we use formulas of the theory of elasticity, taking the load from the aircraft wheels in the form of concentrated forces. The computed values of normal stresses at depth H, necessary for the selection of sections of pipes, are determined by formula:

$$\sigma_r = \frac{KP_k}{H^2} \text{ kgf/cm}^2, \quad (16)$$

where  $P_k$  - pressure from the aircraft load, applied on the surface of the flying field, kgf;

H - depth of location of the point at which we determine vertical stress from the surface of soil, cm;

$r$  - horizontal projection of distance from the point at which we determine the vertical stresses to the point of application of force, cm;

$K$  - coefficient determined depending on ratio  $\frac{r}{H}$

$$K = \frac{3}{2\pi} \cdot \frac{1}{\left[1 + \left(\frac{r}{H}\right)^2\right]^{3/2}} \quad (17)$$

For computation of the full load on the pipe the vertical stresses are totaled for the area of the horizontal projection of the pipe. To obtain the calculated load  $P$  it is necessary to multiply the calculated load by the dynamic-response factor, equal to 1.1-1.15. The load from the weight of the soil above the pipe is calculated by formula

$$Q = K_T \gamma H B_T \text{ kgf/linear cm}, \quad (18)$$

where  $\gamma$  - volumetric weight of soil, kgf/cm<sup>3</sup>;

$H$  - height of filling above the top of the pipe, cm;

$B_T$  - calculated width of trench at the level of the top of the pipe, cm;

$K_T$  - vertical load factor from the soil in the trench, determined by formula

$$K_T = \frac{B_T \left(1 - e^{-A \frac{H}{B_T}}\right)}{HA}; \quad (19)$$

$e$  - Napierian base;

$A$  - coefficient depending on the coefficient of internal friction in the filling soil (for dry sand and clay soils  $A = 0.166$ ; for water-saturated clay soils  $A = 0.122$ ).

The calculated bending moment in the pipe walls is determined by formula

$$M = \frac{0.318}{\pi} (P + Q) r_{cp} \text{ kgf/cm}, \quad (20)$$

where

$P$  - load from the aircraft wheels, kgf;

$Q$  - load from the weight of soil above the pipe, kgf;

$$d_{cp} = \frac{D_{BH} + h}{2} - \text{inner diameter of pipe, cm;}$$

$D_{BH}$  - inner diameter of pipe, cm;

$h$  - wall thickness of pipe, cm;

$N$  - coefficient of support, determined by Fig. 22.

The wall thickness of pipes is determined by the following formulas: for cement pipes

$$M < mR_p \frac{bh^3}{3.5} \text{ kgf}\cdot\text{cm}, \quad (21)$$

for reinforced-concrete pipes

$$M < mR_n b x \left( h_0 - \frac{x}{2} \right);$$

$$x = \frac{m_a R_n F_a}{R_n b}, \quad (22)$$

where

$M$  - the calculated bending moment, determined by formula (20), kgf·cm;

$R_p$  - the calculated tensile strength of concrete kgf/cm<sup>2</sup>;

$b$  and  $h$  - length and thickness of wall of the component being calculated, cm;

$m$  - coefficient of the working conditions is taken as 1.0;

$R_n$  - calculated compressive strength of concrete with bending, kgf/cm<sup>2</sup>;

$x$  - height of the compressed zone, cm;

$m_a$  - coefficient considering the working conditions of fittings;

$F_a$  - area of the section of longitudinal elongated fittings, cm<sup>2</sup>.

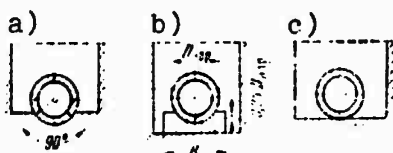


Fig. 22. Methods of laying pipe in the trench: a) normal laying on the bottom of the trench ( $N = 1.50$ ); b) laying on concrete or reinforced-concrete base ( $N = 2.50$ ); c) laying on flat bottom ( $N = 1.12$ ).

Asbestos-cement pipes can be calculated by formulas (20), (21), (22), however, in this case it is necessary to consider the strength indexes of asbestos-cement.

Concrete and reinforced-concrete bases under the pipes are calculated as beams on elastic supports for the effect of load from the aircraft wheels, computed by formula (16). Covers and lattices of manholes, thalweg wells are calculated as beams lying on two supports, or plates, supported along the contour, for evenly distributive load from the aircraft wheels. The walls of manholes and thalweg wells are calculated for horizontal pressure, which is transferred through the soil from the aircraft wheel, located next to the well. The horizontal stresses in the soil are determined by the formula of the theory of elasticity for half-space

$$\sigma_x = \frac{3P}{2z} \left( \frac{x^2 z}{R^3} + \frac{1-2\mu}{3} \left[ \frac{1}{R(R+z)} - \frac{(2R+z)x^2}{(R+z)^3 R^3} - \frac{z}{R^3} \right] \right), \quad (23)$$

where  $\sigma_x$  - horizontal stress in the soil, kgf/cm<sup>2</sup>;  
 P - concentrated force from the aircraft wheels, kgf;  
 R - distance from the point of application of force to the point at which the stresses are determined, cm ( $R = \sqrt{x^2 + y^2 + z^2}$ );  
 x, y, z - distances along the axes of coordinates from the point of application of force to the point at which the stress is determined, cm;  
 $\mu$  - Poisson's ratio for soil.

Formula (21) is derived for the case of application of one concentrated force to the surface of the half-space.

For the computation of stresses from any distributed load we use the common procedure of summation. In this case the distributed load is replaced by a group of concentrated equivalent forces. At each investigated point the stresses from each of such forces are determined and then these stresses are totaled. The volume of computations is reduced many times when using the chart



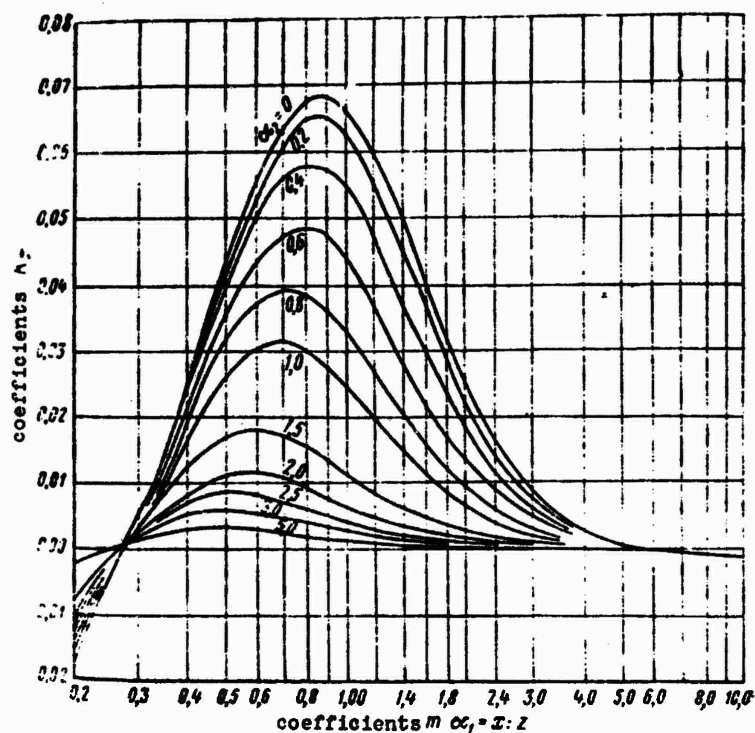


Fig. 23. Chart for computation of stresses with Poisson's ratio  $\mu = 0.3$ .

compiled by G. I. Glushkov. According to the chart by assigned values of  $\alpha_1 = \frac{x}{z}$  and  $\alpha_2 = \frac{y}{x}$  there is determined the value of  $K_x$  and further the horizontal stress in the soil by formula

$$\sigma_x = \frac{p}{2} K_x \text{ kgf/cm}^2. \quad (24)$$

After the determination of horizontal stresses in the soil it is possible to change to the computation of lateral pressure on the walls of the well, for which the calculated pressure must be multiplied by the concentration factor, equal to 1.75-2.00. The bottoms of the wells are calculated as plates leaning on walls, from the action of aircraft load. The caps of sewers should be calculated as revetment walls for strength and stability.

## CHAPTER V

### ARTIFICIAL COVERINGS OF AIRFIELDS

#### § 12. THE PURPOSE OF ARTIFICIAL COVERINGS

The flying field should provide all-year-round non-stop operation of the airfield. The operation of dirt strips of the air field is made difficult during the spring and autumn bad road condition periods, and in summer - with prolonged cloudbursts, when the formation of excess overwetting and the loss of the bearing capacity of the soil are possible. With the location of the flying field on noncohesive, dustforming soils, as a result of intense dust formation in the dry season the safety of operation of aviation on airfields cannot be provided.

The basic measures for maintaining the surface of the flying field in a state suitable for operation are the creation of a stable sod cover, improvement in the conditions of surface runoff because of rational vertical planning and construction of a drainage network. Sod cover strengthens the soil, protects it from soaking during the bad road periods, and in the dry season - from dust formation. Drainage measures accelerate the process of drying out of soils. Sod cover and drainage make it possible during the periods of spring and autumn bad roads, in summer with cloudbursts and with severe dust to reduce the interruptions in the flight activity of aviation. However, in

many instances it is not possible to completely eliminate interruptions in the operation of the dirt strips of the flying field with the aid of sod cover and drainage. During the separate periods of the year the surface of the flying field, especially with its location on clay, loamy, dusty, chernozem soils, rapidly gets soaked and loses bearing capacity. With the location of the flying field on noncohesive (sand) or dust-forming soils, on which the creation of sod cover is made difficult, the surface of dirt strips strongly raises dust and complicates the operation of aviation. During these periods of the year the dirt surface of the flying field is unsuitable for operation.

For the complete elimination of interruptions in the flight activity of aviation and the provision of year-round non-stop operation of the airfield, on the flying field are placed artificial coverings (on the runways, main and branch taxiways, group and individual parking places of aircraft, ramps).

Under favorable soil-ground, hydrogeological and climatic conditions, which prevent overwetting and dustiness of the flying field, artificial coverings cannot be set up on the airfields.

### § 13. FACTORS WHICH AFFECT ARTIFICIAL COVERINGS

The artificial coverings of airfields are subjected to the effect of operational factors, connected with the basing of aircraft, climatic and hydrogeological factors.

Features of the artificial coverings of airfields should be considered the relatively large area of their contact with the base soil, little sinking into the ground active layer and completely exposed surface. This must be borne in mind when

evaluating the effect of each of the indicated factors on the operation of the coverings.

During analysis of the effect of operational factors on the work of artificial coverings it is necessary to consider the intense action of static and dynamic aircraft loads, the gas flow and high temperature from the operating engines. Static design loads correspond to the total takeoff weight of the calculated type of aircraft. For most contemporary aircraft the design load is transferred on the covering with the aid of a three-point landing gear, which consists of one nose and two main struts. The major portion of the load (80-90%) is evenly distributed to the two main struts, and the nose strut absorbs the remaining part of the load.

Depending on the construction of the aircraft the main struts can be with single and multiwheel landing gear. Multiwheel landing gear considerably improve the working conditions of coverings because of the load distribution on a large area. The simplest type of multiwheel landing gear is a strut which has two dual wheels (Fig. 24a). Even better working conditions of coverings are provided by the supporting point of the aircraft, which has four wheels (Fig. 24b). The use of dual and quadrupled wheels on the aircraft struts makes it possible to considerably reduce the thickness of coverings. Besides the static loads, characteristic for aircraft parking places, airfield coverings are subjected to dynamic loads from aircraft moving at high speed during taxiing, takeoffs, landings and braking.

In connection with the effect of lift and different speeds of the aircraft the amounts of loads affecting the coverings are dissimilar. On the ends of RW with normal landing the dynamic loads insignificantly exceed the static, and in a number of cases are even less than it. The dynamic load can reach even larger value after the first impact of wheels on the covering, but its

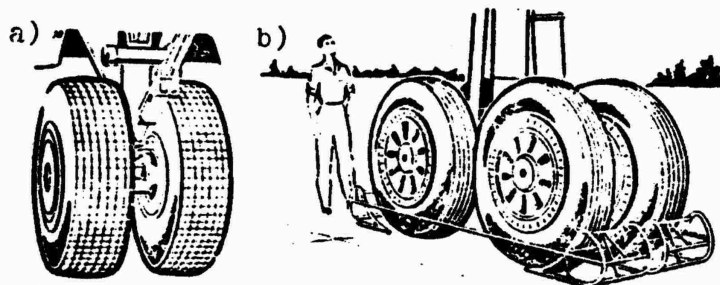


Fig. 24. The main struts of contemporary aircraft.

absolute value differs little from the static load. The time of action of impact loads during aircraft landings is calculated in fractions of a second. Observations showed that considerable deterioration in the working conditions of coverings does not occur with landing shocks. This is confirmed by the results of the inspection of the state of coverings at different airfields, which showed that on sections where aircraft landings occur the coverings, as a rule, do not have serious failures.

During aircraft movement in the process of taxiing, takeoffs and landings, as a result of the local natural roughness of coverings (tearouts, potholes, offsets in joints, etc.) aircraft vibrations are developed, in consequence of which the actual loads on the covering increase. The speed of aircraft has a considerable effect on the amount of load. During aircraft movement at low speed the pneumatic tires of the wheels during the passage over roughness are squeezed and do not cause sharp increase of the load on the covering. From a speed increase of aircraft there are observed shocks of wheels against the covering, and loads on the covering increase. With further speed increase lift begins to be developed which receives part of the aircraft weight, and the load on the covering is substantially decreased.

The greatest loads on the coverings are during aircraft motion at speed 30-40 km/h, when the effect of lift is small. The amount of load on the covering much depends also on the state of

its surface. On sufficiently even coverings the dynamic loads insignificantly exceed the static. With roughness up to 1-2 cm high the dynamic loads increase by 20-30% as compared with the static loads. With roughnesses 3.5-4.0 cm high the increase in the dynamic loads reaches 30-45%. Besides vertical forces, the coverings of airfields are affected by the horizontal forces which appear from the shocks of wheels when rolling on the roughness and from the friction of pneumatic tires during aircraft braking. The wear of coverings and the possibility of the formation of waves and shears on asphalt-concrete and crushed stone coverings treated with organic binder depend on horizontal forces.

During the power test of engines the covering is affected by vibration. Tests of the covering by aircraft with operating engines on the aprons showed that a considerable increase in the loads on the coverings does not occur in these cases. On the parking places the aircraft are in static state a long time. At the parking places they exit at low speeds, therefore the dynamic effect of the load will be minimum.

Thus, those sections of coverings where the aircraft moves at speed 30-40 km/h are under the most adverse working conditions under the action of aircraft loads. Such sections include main taxiways. End sections of RW, connecting and auxiliary taxiways, where aircraft move at low speeds, are under more favorable conditions.

The middle sections of the RW, where the aircraft speed reaches considerable values, experience lesser loads. The aircraft parking places where the loads bear a static character are in the best conditions.

The difference in the operation of the middle and end parts of the RW is evident from the chart (Fig. 25) of the distribution

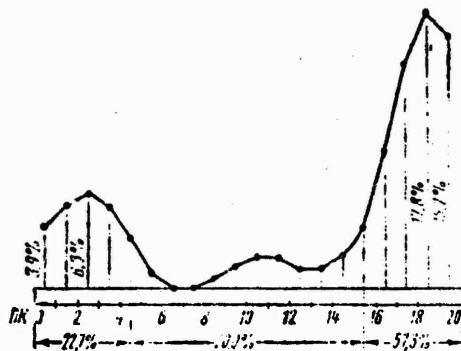


Fig. 25. Chart of distribution of surface failures of plates along the length of the RW.

of slabs with surface failures along the RW length. The basic mass of deformations is concentrated on the end sections, where the aircraft speed is considerably less than in the middle part. In quantitative respect the dynamic action of aircraft loads on the covering can be characterized by dynamic-response factor  $K_{дн}$ , which shows an increase of forces in the covering from the effect of the dynamic feature of the application of loads and can be quantitatively defined as the relationship of deflections of the covering with dynamic  $W_{дн}$  and static  $W_{ст}$  loads

$$K_{дн} = \frac{W_{дн}}{W_{ст}}. \quad (25)$$

For contemporary aircraft the dynamic-response factor is changed from 1 to 1.20.

The observations and calculations show that the large jet and turbojet aircraft will sufficiently accurately touch down along the axis of the RW. From the distribution of the landing places of large aircraft along the width of the RW, obtained by foreign investigators (Fig. 26), it is clear that on the center section of the strip there occur about 50% of the takeoff and landing runs. On the RD, especially on the main, the aircraft wheels move along one track, which considerably increases the repetition of application of loads. Thus, the working conditions on coverings on the RD and on the middle part of the RW are the most

severe, which is considered by the increased amounts of thickness of coverings on these sections.

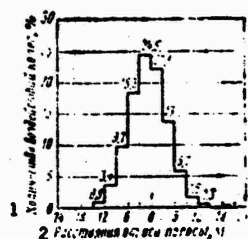


Fig. 26. Distribution of aircraft motion during takeoff and landing runs (according to foreign investigations).

KEY: (1) Quantity of actions of wheels, %; (2) Distances from the axis of strip, m.

The strength of the edge (side) sections of the RW coverings on both sides of the axial strip, and also the MS can be decreased 10-15% in comparison with the strength of the central section.

Besides loads from the weight of the aircraft, the covering is affected by the air stream from a recip-engine aircraft and the flow of exhaust gases of jet engines, and also tearing forces as the consequence of the effect of suction during engine operation.

The streams of contemporary turbojet engines with maximum revolutions have gas temperature 600-800°C, and speed on leaving the nozzle - 600 m/s. Upon contact with the covering the temperature of the stream is lowered to 250-350°C, and the speed - to 10 m/s. The stream at the place of contact with the covering is propagated to an area of elliptical shape, called the field of the stream. For contemporary aircraft the length of the stream field is 50-60 m under taxiing conditions and 80-100 m under maximum rpm conditions; the maximum width of the stream field is 20-30 and 30-50 m respectively. The duration of the effect of the stream of exhaust gases of jet engines on the covering on the average is: during engine runup (nominal rating) at the parking places 3-5 min; at rest on the takeoff area with low rpm 2-3 min; at rest on the takeoff area when waiting for takeoff clearance (nominal rating) 1-2.5 min.



On RW, where the aircraft moves at larger speed, and the duration of the effect of the stream is short, the artificial coverings are not highly heated. For the takeoff sections of RW and MS of aircraft the high temperatures (up to 200°C) and high gas flow velocities (up to 100 m/s) constitute a danger to artificial coverings. Therefore these sections of coverings, and also the sections of the flying field adjacent to the ends of the RW and taxiways, where the stream of exhaust gases burns out the plant covering, should be reinforced. For the elimination of the dangerous effect of the stream it is possible to use sloping concrete barriers or latticed shields, which deflect the gas stream upward.

No less important effect on the operation of artificial coverings have climatic and hydrological factors. Artificial coverings are subjected to the action of natural factors - variable temperature-moist conditions, swelling or expansion of the underlying soils, repeated freezing and thawing, to the action of solar radiation, wind erosion, etc.

The frost swelling, which occurs because of the segregation of ice, separating in the form of layers, leads to an increase in the total volume of the freezing rock mass of the soil and the vertical rise of its surface. Stresses being developed in the artificial coverings under the action of variable temperature conditions can cause breakage. They are especially dangerous for long concrete slabs. Of vital importance for the development of temperature stresses in coverings is solar radiation. Repeated freezing and thawing can lead to breakage of coverings or the appearance of separate cracks. Natural factors should be considered during selection of the type and construction of artificial coverings.

For a decrease in the harmful effect of natural factors one should use materials of high quality and strictly observe all the technical specifications during their treatment and use.

#### § 14. BASIC REQUIREMENTS FOR ARTIFICIAL COVERINGS

The constructions of the coatings should be economical, have high bearing capacity, which does not depend on the time of the year and the condition of the ground on the flying field. During the operating action of aircraft wheels the coverings should be little worn and well resist the action of the stream of exhaust gases of jet engines, be resistant to the harmful action of fuel and lubricants. Therefore, when designing artificial coverings great significance is given to the selection of rational constructions, to the use of materials of good quality and to stabilization of the soil base. The basic requirements imposed on artificial coverings include: strength, reliability and durability; lack of dustiness of surface; smoothness and sufficient roughness, which creates adhesion of the aircraft wheels with the covering; resistivity to climatic and hydrological factors; impermeability, which prevents the penetration of surface water into the ground base; resistivity to the action of the exhaust gas stream of jet engines; resistance to the action of fuel and lubricants; economy, simplicity of construction with maximum use of mechanization means; simplicity of care of the covering during repair and maintenance; the possibility of use of local construction materials; the possibility of rebuilding of coverings with the appearance of new types of aircraft with high speeds of travel and loads on the strut.

## § 15. THE TYPES OF ARTIFICIAL COVERINGS, THEIR CLASSIFICATION AND FIELD OF APPLICATION

Two types of artificial coverings are used on airfields - rigid and nonrigid. Rigid coverings possess the ability to absorb the tensile stresses caused by the action of aircraft load and by temperature-shrinkage factors. The covering under load works as a plate on an elastic base; deformations of the covering, as a rule, are elastic, and pressure of the slab to the soil is small. The rigid include: coverings made of prestressed cast in-situ concrete and reinforced concrete; precast prestressed reinforced-concrete slabs; cast in-situ reinforced concrete; concrete and reinforced concrete coverings.

Nonrigid coverings do not absorb tensile stresses. Their resistance to aircraft loads is explained by the resistance of the underlying soil to compression and side squeezing. In the spring and autumn bad road periods the pressure on the ground reaches a considerable magnitude, and the deformations of coverings bear a plastic character. Nonrigid type coverings include: asphalt-concrete; rough crushed stone and gravel, constructed by the method of impregnations or by mixing on the spot; from soils reinforced by binding agents.

Depending on the service life and structural features the artificial coverings are divided into major, improved, simplified and temporary. The major types of coverings are applied on airfields intended for the operation of large jet and turbojet aircraft. They allow a large quantity of takeoff and landing operations and have long service life. Major coverings include rigid coverings, asphalt-concrete, and also rough crushed stone coverings, constructed by the impregnation method.

The improved coatings are used on airfields intended for the operation of medium aircraft. The improved coverings

include rough crushed stone, constructed by the method of mixing on the spot, and gravel coverings, treated with organic binding agent.

Simplified coatings are used with operation of the airfield by light aircraft. The coverings are constructed from soils, reinforced with binding agents. Temporary coverings after use allow dismantling, transportation and installation on another airfield. Temporary coverings include coverings of steel, plastics and light alloys. The types and constructions of artificial coverings are established depending on the category of the design load, climatic and hydrological factors with the necessary technical and economical substantiation and the presence of local building materials.

#### § 16. PRINCIPLES OF TESTS OF ARTIFICIAL COVERINGS FOR STRENGTH AND DURABILITY

For checking the reliability of construction tests are conducted of artificial coverings by static and moving dynamic loads for the purpose of determining: the magnitude of permissible operational and breaking loads for coverings of different types; the amount of deformations during operation in elastic and plastic stages; the maximum permissible quantity of applications of loads for coverings of various types; the amount of deformations during the action of calculated loads and change of the temperature conditions.

Tests are conducted on the coverings of airfields, and also on specially constructed test sections with coverings of different constructions. In the process of construction of the covering we lay special equipment, which makes it possible to determine the deflections and relative deformations, and also the stresses in the base and the underlying soil. The coverings are tested both

in the summer and during the most adverse periods of the year (spring, autumn).

For static tests there are used installations which permit creating a load on the covering (Fig. 27). The installation consists of two metal beams 24 m long, resting on bogies with aircraft wheels, and is outfitted with a set of hydraulic jacks with load-lifting capacity from 5 to 200 t. The beams are loaded with ballast of cast iron ingots and serve as a detent for the hydraulic jack during the loading of coverings. The coverings are tested with rigid metal stamps of various diameter. The deflections of coverings are measured by mechanical indicators with accuracy of reading 0.01 mm, which are fastened to a special reference tubular truss. The elongation of the upper fibers of coverings is determined by wire-type resistance strain gauges with base 100 mm.



Fig. 27. Installation for static tests.

#### § 17. FEATURES OF FOREIGN ARTIFICIAL COVERINGS

For testing the coverings for the effect of moving dynamic loads mobile units are used (Fig. 28). The installation consists of a platform with sections for weights and a four-wheeled aircraft strut. It is towed by the YaAZ-210 truck-tractor at speed up to 50 km/h. The coverings are tested with repeated passage along one track (conditions of loading characteristic

for the taxiways) and over the entire area (conditions characteristic for the runway).



Fig. 28. Installation for testing coverings with moving loads.

Figure 29 depicts the test results of rigid concrete coverings with static load. Figure 30 gives the curves illustrating the state of different type coverings during their testing with moving load.

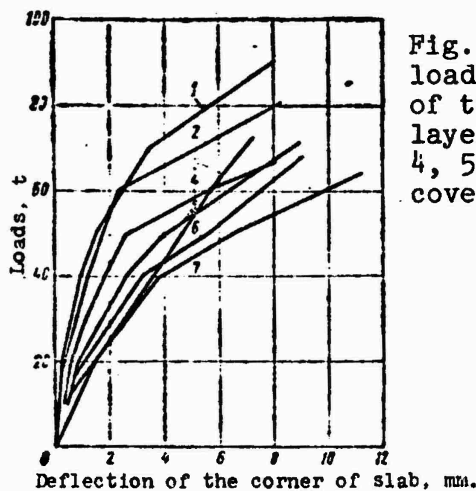
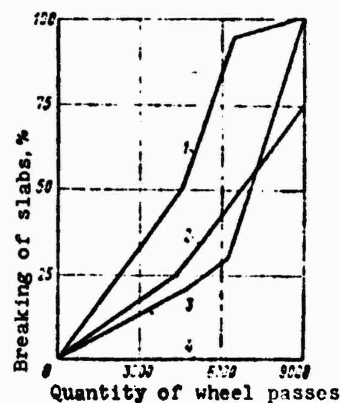


Fig. 29. Relationship between the load and deflections of the corner of the slabs: 1, 6 - with two-layered concrete coverings; 2, 3, 4, 5, 7 - with single-layer concrete coverings on a sand base.

Fig. 30. Curves of the state of coverings depending on the quantity of passes of the testing unit: 1, 2 - single-layer concrete coverings with reinforcement of the edges of the slabs for through joints with three rods 12 mm in diameter; 3 - single-layer concrete coverings with keyed connection of slabs in the joints; 4 - two-layer and single-layer concrete coverings with bolted connections in transverse joints.



Foreign artificial coverings have much in common with the constructions used in the USSR. Abroad there are also used two basic types of coverings - rigid and nonrigid. Rigid coverings are constructed, as a rule, as reinforced concrete and from cast in-situ concrete. Precast reinforced-concrete coverings abroad are not widespread. In recent years cast in-situ prestressed coverings were widely spread. Nonrigid coverings consist of a supporting layer and a bitumen-impregnated top layer. The supporting layer is constructed from stone, slag, caliche<sup>1</sup>, gravel, limestone, shellrock, sand-clay mixture, corals, earth and cement or thin rolled concrete. All the enumerated materials, except the last two, can be connected by bitumen or other binding materials.

The technical specifications abroad provide for the wide use of local building materials. Considerable attention is given to detailed determination and evaluation of the properties of natural soil bases.

The international airport Schiphol in Amsterdam has two-layered rigid concrete coverings: top layer 22 cm thick, lower - 30 cm. Between the layers of concrete a layer of sand with thickness 2 cm is created. The covering is laid on a base of crushed stone 15 cm thick and sand 30 cm thick. The covering is designed for aircraft weighing up to 300 t.

The covering of the La Guardia airport in New York is made of crushed stone treated with organic binding agent. The bearing capacity of the covering corresponds to design load on one wheel 36,300 kgf. The Bonn airport of Cologne is equipped with a new RW with prestressed covering. The prestressed coverings are also applied in France at the Orly airfield and in England on the London airfield. In England cast in-situ

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<sup>1</sup>Caliche - saltpeter-containing hard rock.

cement-concrete coverings are widely used. The thickness of slabs is restricted to 30 cm, since the equipment used cannot provide satisfactory packing to a great depth. If necessary two-layered coverings are used. The covering, which withstands wheel load 45 t, consists of a top concrete layer 30 cm thick and bottom layer 20 cm thick.

Abroad much attention is given to improvement in the evenness of coverings, which is necessary for decrease of the harmful action of vibration during aircraft takeoffs and landings.

Great significance is given to care during the construction of concrete coverings. Care of concrete is fulfilled the most thoroughly in the first hours and first days after laying. These measures are directed toward improvement in the quality of the construction of artificial coverings.



## CHAPTER VI

### BASES OF ARTIFICIAL COVERINGS OF AIRFIELDS

#### § 18. SOILS AS THE NATURAL BASES OF COVERINGS

The soils as bases should absorb the pressure from the load being transferred through the coverings, without allowing dangerous deformations in this case.

In concrete and reinforced-concrete coverings, which possess considerable rigidity, there appear insignificant deflections from the load, therefore the reaction being developed by the underlying soil will be small. The strength of such coverings depends to a greater extent on the strength of the material of coverings themselves than the mechanical properties of the soil base. The breakage of rigid coverings occurs, as a rule, with loads less than those which are necessary for the loss of stability of the soil base according to the theory of limiting equilibrium.

In nonrigid coverings there appear considerable deflections from load, therefore their strength mainly depends on the strength characteristics of the soil base.

The classification of soils, provided in Table 18, is taken depending on the content of clay, silty and sandy particles.

Table 18.

Type of soil	Number of plasticity	Content of fractions, % by weight		
		Sandy	Silty	Clay
		2.0-0.05 mm	0.05-0.005 mm	Less than 0.005 mm
Sands: gritstone, coarse-grained, medium-grained, fine-grained	0	-	<15	<3
Silty sands	-	More than silty	15-50	<3
Sandy loam	-	Particles 2.0-0.25 mm over 50%	Less than sandy	3-12
Fine sandy loam	1-7	Particles 2.0-0.25 mm less than 50%	Less than sandy	<12
Silty	-	-	More than sandy	<12
Loam	-	More than silty	-	12-18
Loess loam	7-17	Particles coarser than 0.25 mm are almost absent	>50	3-18
Silty	-	-	More than sandy	12-25
Heavy	-	More than silty	-	18-25
Clay	>17	-	-	>25

Sandy soils are additionally classified according to the data provided in Table 19. First the soil is determined from Table 18 and, if it falls in the category of sandy, its name is additionally more precisely defined by Table 19.

Table 19

Type of soil	Indexes of size distribution
Detritus (pebble) soil	Weight of fractions, 10 mm over 50%
Rotten soil (gravel)	Weight of fractions, 2 mm over 50%
Gritstone sand	Weight of fractions, 2 mm 25-50%
Coarse-grained sand	Weight of fractions, 0.5 mm over 50%
Medium-grained sand	Weight of fractions, 0.25 mm over 50%
Fine-grained sand	Weight of fractions, 0.1 mm over 50%
Silty sand	Weight of fractions, 0.1 mm under 75%

Note. The type of sand is established by means of sequential summation of percentages by the weight of the content of particles first coarser than 2 mm, then 0.5 mm, 0.25 mm and is taken according to the first satisfactory index in the order of arrangement of names in the table.

The mechanical properties of soil bases as a result of the action of natural factors are highly changed during a year and a number of years. They are subjected to moistening, to drying out, to freezing and thawing of surface layer. An increase in the moisture of soils leads to a reduction in their bearing capacity, this is greater the more silty and clay particles that are contained in the soil.

A temperature decrease of the soil within the limits of its plus temperatures is accompanied by an increase in the viscosity of water in the pores, which leads to some increase in its bearing capacity. Freezing of the soil is accompanied by the accumulation of ice in its pores, by increase in the volume and by the loosening of the freezing layer. Because of this in winter there is noted a rise of the surface of soil, called frost swelling. Frozen soils are practically incompressible and possess greater bearing capacity. In the spring the ice in the soil melts, the pores of the loosened soil are filled with water and the compressibility of the base is sharply raised, which leads to a considerable reduction in the bearing capacity of the soil. During the summer period the soil dries and its bearing capacity increases.

The effect of water and thermal conditions on the bearing capacity of soils in the bases of constructions shows up to a considerably lesser degree than in the bases of coverings, since the foundations of constructions will usually lie lower than the freezing depth, where the soil has sufficiently stable conditions of temperature and moisture and therefore the modulus of deformation is little changed during a year.

The bases of coverings, as indicated above, during the separate periods of the year sharply change bearing capacity and become very nonuniform in depth. In the works of many scientists there is emphasized the necessity for planning road surfaces and coverings of airfields on the strength of the calculated state of the soil base, when its bearing capacity is the lowest. On a considerable part of the territory of the USSR the calculated state begins with the thawing of frozen soils during the spring bad road period, and in the majority of cases - at the moment of the complete thawing of the entire frozen layer of soil. Therefore, the parameters of soil, taken during the calculation of coverings and which characterize its bearing capacity (modulus of deformation, the coefficient of substratum), should correspond to the calculated state of the soil base.

The annual cycle of change in the moisture, density and the bearing capacity of soils, equally regular in all areas where seasonal freezing and thawing take place, is quantitatively developed dissimilarly under different natural conditions.

V. V. Dokuchaev established the presence of a definite connection between the water conditions of soils and the climate and hydrogeological conditions of the locality. The water balance of the atmosphere - arrival in the form of precipitation and consumption in the form of evaporation - basically stipulates the water balance of soils. Proceeding from this the Soyuzdornii [State All-Union Scientific Research Institute of Roads and

Highways] compiled the chart of the climate zones of the territory of the USSR, given above. Each climate zone has its predominant types of soils:

Climate zone I	Tundra, podzolic soils
Climate zone II	Podzolic
Climate zone III	Podzolic, chernozems, gray podzolic
Climate zone IV	Chernozems, chestnut, alkaline soils
Climate zone V	Chestnut, brown, alkaline, solonchak soils, scattered sands.

These data are compiled on the basis of analysis of the distribution of the soil cover inside road-climate zones.

Besides the general climatic regularity, the water conditions of soils are also affected by local sources of excess moistening (surface or ground water). Within the same climate zones depending on the ground water level and the runoff conditions of the surface water the autumn reserves of moisture in the soils can considerably differ. Therefore the calculated moisture of soils should be estimated taking into account the hydrogeological conditions of the locality, which are divided into three types (Table 20) according to the technical specifications of the designing of airfield coverings (SN 120-60).

The noted hydrogeological conditions should be considered when designing the artificial coverings.

Table 20.

Type of hydrogeological conditions	Characteristic of terrain	Depth of the level of ground water or vadose water from the surface at the beginning of freezing	Category of the moisture which is contained in the soil at the beginning of its freezing to a depth of 0.25-0.5 m from the surface
I	Dry places without excess moistening with provided surface runoff, low level of ground water and, as a consequence of this, the absence of capillary rise of water to the active working region of the soil.	Greater than the sum of the freezing depth and the height of capillary rise.	From hygroscopic to molecular moisture content.
II	Temporary excess moistening by surface water, caused by poor filtration of soils and by insufficient surface drain with low level of ground water.	Greater than the freezing depth.	From maximum molecular to maximum capillary moisture capacity.
III	Constant excess moistening, caused by high level of ground water or vadose water in the autumn period, by a large number of annual deposits with poor filtration of soils and insufficient surface drain and, as a consequence of this, by capillary rise of water to the active working region of the soil.	Less than the freezing depth	From maximum molecular moisture capacity to complete saturation of pores by gravitational moisture.

Note. The indicated division is not extended to mountain areas, where the climate depends on the height of the terrain above sea level and can be sharply different at points located close to one another. Such areas are characterized by the weather data obtained directly on the spot.

## § 19. THE BASIC MECHANICAL MODELS OF SOIL BASES

A feature of the calculation of coverings involves the necessity for account of the reaction forces of the soil base besides the effective forces from external actions. For this are necessary mechanical indexes, which characterize the ability of soils to resist the effective loads and determine the features of development of deformations of the soils under the action of these loads.

The processes of deformation of soils under load are extremely complex and varied. A precise account of the natural mechanical properties of the soil is practically impossible. Usually during calculation of coverings it is necessary to introduce some schematization of the mechanical properties of the soil by means of the replacement of the natural ground base by some calculated model, whose properties are known. Consequently, the more accurately the accepted calculation model will reflect the behavior of the ground base under the covering, the more precise the results of calculation will be.

When selecting the calculation model it is necessary to see that it depicts the mechanical properties of the soils with a minimum quantity of parameters, since for such a nonhomogenous medium -s soils each parameter is determined approximately as a mean-integral value. Therefore the fewer the parameters the taken calculation model will contain, the fewer the approximate values that will be introduced into the calculation of coverings.

The most widespread in the practice of designing of constructions, which rest upon natural soils, was the simplest model based on Winckler's hypothesis. This model has the following assumptions:

a) constructions and bases are connected with each other in vertical direction so that any movements of the construction involve the same movements (settling) of the base in the same place;

b) the construction is not connected with the base in horizontal direction, therefore shifts relative to the base are possible;

c) the amount of vertical movement (settling) of the base is proportional to the intensity of the load on it.

This model can be represented schematically in the form of a number of separate indentical springs, installed on a rigid base and each working independently of one another.

The mechanical properties of the material of the model are characterized by one parameter - proportionality factor, which it is accepted to call the substratum coefficient. Therefore this model is usually called the model of a base with one substratum coefficient. The substratum coefficient ( $\text{kgf/cm}^3$ ) is numerically equal to the load which must be applied to a unit of area of the base, in order to create unit vertical deformation.

The relationship between the reaction of the base and its settling is expressed by formula

$$p = Cw, \quad (26)$$

where  $p$  - reaction of base,  $\text{kgf/cm}^2$ ;

$C$  - substratum coefficient,  $\text{kgf/cm}^3$ ;

$w$  - settling of base, cm.

The main disadvantage of a model with one substratum coefficient involves the fact that it does not possess the property to "distribute" load, whereas experiments show that the surface



of soil is deformed beyond the limits of the loaded part.

The model of elastic half-space, in which the soil is considered as an elastic isotropic solid, and the deformation distribution on its surface is taken according to Boussinesq's hyperbolic law is free from the indicated shortcoming. According to this model the soil base is deformed beyond the limits of the loaded part. In this case deformations are extended to the sides to infinity, gradually attenuating in proportion to the distance from the loaded part. The mechanical properties of the material of the model are characterized by two parameters: modulus of deformation  $E$  and Poisson's ratio  $\mu$ .

The mechanical parameters of soils are determined on the basis of the results of field tests by a test load, carried out by a special procedure.

The procedure for field determination of parameters of the soil.

For tests we use round rigid punches, metal or concrete with diameter 700-1000 mm. The tests are conducted in the spring bad road period, when the bearing capacity of the soil base has the smallest value. The places of conducting tests are arranged along the supposed directions of coverings, in this case we select the characteristic sections, the condition of soils on which is typical for the entire object. Simultaneously with tests by indentation of the punch for the purpose of determining the grain-size distribution, volumetric weight, moisture and other characteristics the soils are tested in the laboratory by the ordinary procedure in accordance with standards and rules.

When setting up the die the close fit of its lower surface to the soil should be provided for. For this after the removal of

the plant layer the soil is levelled and on it is packed a quick-setting cement mortar with layer 2-3 cm, to which the punch is tightly installed. As instruments for measurement of settlements we use dial indicators with scale value 0.01 mm. During tests together with the determination of deformations of the surface of soil under the punch we measure the deformations of surfaces outside the punch. The instruments are placed on the punch (three indicators) and on the surface of the soil (in two directions along the axis of the punch), in a zone equal to 1-1.25 the diameter of the punch. Instruments are placed in the immediate vicinity of the punch at a distance of 5-10 cm from one another. In proportion to the distance from the punch this distance is increased to 20 cm. The first instrument is installed at a distance of 2 cm from the edge of the punch. The load on the punch is applied in stages: 0.2, 0.4, 0.8, 1.2, 1.4, 2.0 kgf/cm<sup>2</sup>, whereupon after each stage of loading we perform unloading for measurement of the residual deformations of soil. The readings of the instruments are taken after stabilization of settling. The settlements are considered stabilized if during 10 min the difference in readings does not exceed 0.01 mm. The described sequence of tests makes it possible to calculate all the parameters of the soil base (modulus of deformation, substratum coefficients) necessary for the calculation of coverings.

The modulus of deformation of the soil is calculated on the strength of complete stabilized settlements of the punch at each stage of loadings according to the method of I. I. Cherkasov. During the calculation of rigid coverings the basic calculation parameter is considered the modulus of deformation, which corresponds to complete settling of the punch.

$$\frac{w_s}{D_{st}} = \frac{1}{10000}.$$

In view of the fact that the indentation curve, constructed by complete settlements, is expressed by dependence

$$p = A \left( \frac{w_0}{D_{\text{шт}}} \right)^n \quad (27)$$

and the exact coincidence of relative settling of the punch on one of the stages of loading with value

$$\frac{w_0}{D_{\text{шт}}} = \frac{1}{10000}$$

is highly improbable, computation must be performed with the aid of nonlinear interpolation.

Parameters of indentation curve  $A$  and  $n$  are calculated by formulas:

$$n = \frac{N \sum \lg p \lg \frac{w_0}{D_{\text{шт}}} - \sum \lg \frac{w_0}{D_{\text{шт}}} \sum \lg p}{N \sum \left[ \lg \frac{w_0}{D_{\text{шт}}} \right]^2 - \left[ \sum \lg \frac{w_0}{D_{\text{шт}}} \right]^2}; \quad (28)$$

$$\lg A = \frac{\sum \lg p - n \sum \lg \frac{w_0}{D_{\text{шт}}}}{N}, \quad (29)$$

where  $p$  - specific pressure on each stage of loading,  $\text{kgf/cm}^2$ ;

$w_0$  - complete settling of punch on the same loading stage, cm;

$D_{\text{шт}}$  - punch diameter, cm;

$N$  - number of loading stages, at which  $w_0$  and  $p$  were determined;

$n$  - degree of strengthening;

$A$  - hardness number.

Then we calculate the modulus of deformation for the prescribed relative settling by formula

$$E_0 = \eta (1 - \mu_0^2) \frac{E}{4} A \left( \frac{w_0}{D_{\text{шт}}} \right)^{n-1} \text{ kgf/cm}^2 \quad (30)$$

where  $\mu_0$  - Poisson ratio, taken from  $\mu_0 = 0.25$  for sand to  $\mu_0 = 0.4$  for clay;

$\eta$  - correction factor for the thickness of the layer being compressed;

$\frac{w_0}{D_{\text{шт}}}$  - relative settling of punch (in this case  $\frac{w_0}{D_{\text{шт}}} = 1/10,000$ ).

The value of  $\eta$  is determined depending on the ratio of the thickness of the layer being compressed to the punch diameter  $\frac{h_0}{D_{\text{шп}}}$  according to the following data:

$h_0/D_{\text{шп}} \dots$	0.125	0.250	0.500	1.000	2.000	10.000
$\eta \dots$	0.141	0.258	0.457	0.682	0.825	1.000

The thickness of the  $h_0$  layer being compressed is determined on the spot according to the results of experiments by indentation of the punch or is taken according to Table 21.

Table 21.

Soil	Ratio of the thickness of compressible layer to the radius of punch		
	Limits of change		Mean Value
	From	To	
Gravelly sand with gravel content from 10 to 50%	1.95	2.04	2.0
Fine-grained sand	1.96	3.64	2.5
Silty	2.22	2.94	2.5
Silty sandy loam	2.04	2.40	2.2
Sandy loam	1.79	2.57	2.1
Light loam	2.04	2.26	2.2
Silty	1.71	3.18	2.3
Loess	1.88	2.10	2.0

By the described method we determine the modulus of deformation by the results of each individual experiment. Then by the generalization of results of a number of experiments we calculate the averaged moduli of deformation of the characteristic strata and, finally, the entire soil base as a whole.

The substratum coefficients are calculated on the strength of complete stabilized settlements at each stage of loading by formula

$$C = \frac{p}{\pi r^2 w_0} \text{ kgf/cm}^3 \quad (31)$$

where  $p$  - total pressure at each stage of loading, kgf;  
 $r$  - radius of punch, cm;  
 $w_0$  - complete settling of punch on the same stage of loading, cm.

On the basis of the performed computations we construct graphic relationships of the values of substratum coefficients to the value of complete settling  $C = f(w_0)$ . The computed value of the substratum coefficient is determined according to curve  $C = f(w_0)$  for the taken value of calculated settling.

## § 20. ARTIFICIAL BASES

Artificial bases of coverings raise the bearing capacity of the soils, especially during the period when they are in the overmoistened state; they regulate the conditions of moistness of the underlying soils; they prevent the squeezing of the diluted soil through the joints of the covering under the action of moving operational loads on the covering and prevent the breakage of coverings from swelling.

Depending on the place of location of the airfield and the effect of loads on the covering it is possible to construct the bases sand, from sand-gravel mixtures, from crushed stone or gravel, treated in the top layer with organic binding materials, and also from sand or thin concrete or cement-soil. For selection of the type of base technical and economic comparisons of the variants are necessary.

The simplest type of artificial base under the concrete covering is a sand base, which improves the working conditions of the coverings on the whole in connection with the constant bearing capacity of sand, low coefficient of friction of the covering against the sand base and its draining ability. As a rule, between the concrete slabs and the sand base there should be placed a separating layer made of grease-proof bitumen-impregnated paper and others. For the construction of sand bases we use irregular sands, which conform to the requirements given in Table 22.

Table 22

Sand	Size of the openings of sieves, mm					Content of silty-clay particles (finer than 0.05 mm), % by weight	
	2	1	0.5	0.25	0.15	Zone of moderate moistening	Zone of excess moistening
	Quantity of particles which are held on the sieve						
Coarse	Up to 35	≥50	-	≥90	-	7	5
Medium	Up to 20	-	≥50	≥75	≥90	5	4
Fine	Up to 10	-	-	≥50	≥90	4	3
Extra-fine	-	-	-	≥60	≥90	4	3

It is permitted to use fine-grained and extra-fine sands for the construction of bases only when special measures are provided, which ensure the stability of the sand layer, for example, the introduction of coarse-grained, additions, treatment with binding agents, etc.

Crushed stone and gravel mixtures are used for the construction of bases only in the absence of danger of the mutual penetration of gravel and the underlying layer of soil. For the

construction of bases the gravel mixture should satisfy the requirements given in Table 23.

Table 23.

Sizes of fractions, mm	Content of fractions for II and III climate zones, %	
	Dry Locality	Damp Locality
>25	52-36	68
25-5	30-40	20
5-0.5	15-20	10
<0.5	3-4	2

In all cases of the construction of bases from gravel-crushed stone mixture it is desirable to pack the soils of the underlying layer to a depth of 10-15 cm. Soils cannot be reinforced when the mechanical composition of the gravel-crushed stone mixtures is selected to fit the composition of the soil of natural base by the type of selection of the filtering filter for drains.

Strengthening of soils of the base, as a rule, can be accomplished in the III-IV climate zones. In the II climate zone light loamy, sandy loam and other coarse-grained soils can be subjected to strengthening. As strengthening additions at the present time we use organic and inorganic binding agents: liquid bitumen, liquid coal and peat tars, high-resinous petroleums, portland cement, slaked and unslaked lime. The use of lime for the strengthening of bases under rigid coverings are limited to IV and V climate zones in view of its insufficient frost resistance. More detail about the use of different methods of strengthening of soils, and also requirements for binding materials, the technology of construction of strengthened bases are given in the Instructions for the use of soils strengthened by binding materials (SN 25-64) in road and airfield construction.

The thickness of the sand or gravel layer according to technical specifications of the designing of airfield coverings (SN 120-60) should not be less than that indicated in Table 24.

Table 24.

Soil of base	Climate zones		
	II	III	IV
	Recommended thickness of base made of medium- and coarse-grained sands, cm		
Sandy	15	10	10
Sandy loam	20-25	15-20	10
Heavy loam and clay	25-30	20-25	15
Silty soil and silty loam	35-50	25-40	15-20

Note. Greater thickness should be taken for areas in the northern part of this climate zone, and lesser - the southern.

The sand and gravel-crushed stone bases of small thickness (up to 10 cm) can be set up under favorable hydrogeological conditions mainly in the southern areas for the prevention of freezing of the covering together with the soil. If the sandy soils conform to the requirements of Table 22, the construction of artificial base is not provided.

Coverings can be constructed without sand or gravel-crushed stone base, as a rule, only in exceptional cases with the presence of sandy soils and under especially favorable hydrogeological conditions. The bases, laid out in sections, with soils subject to swelling, have their peculiarities.

It is recommended to select constructions of rigid coverings and their bases with the presence of swelling soils in the natural



base so that the coverings would allow the greatest possible deformations without failures, and the bases would facilitate a decrease of the swelling to permissible limits. In this case conditions of the safety of aircraft motion should be observed.

On the strength of conditions of safe operation of aircraft for concrete coverings there are established tentative maximum permissible roughnesses, connected with heaving (Table 25).

Table 25

Element of flying strip	Offsets on the joints of adjacent slabs (only for freely lying slabs), mm	Mounds and holes at joints, mm	Algebraic difference
Taxiways	15	15	0.009
Runways	10	10	0.006

Note. The maximum permissible roughnesses are given for aircraft which have tire pressure up to 10 kgf/cm<sup>2</sup>.

If with respect to the prediction of swelling the deformations of the covering turn out to be equal to or less than the maximum permissible, than there are no limitations of the construction of covering and base.

## CHAPTER VII

### RIGID COVERINGS OF AIRFIELDS

#### § 21. BRIEF INFORMATION ABOUT THE DEVELOPMENT OF RIGID COVERINGS

In the Soviet Union rigid coverings began to be constructed on airfields in 1932-1933. These were coverings made of concrete hexahedral slabs 10-14 cm thick with dimensions of the side 1.25 m. The slabs were placed by hand. Coverings of such type were constructed up to 1941 and in the first postwar years and they reliably ensured the operation of the aircraft of that period. However such coverings are unsuitable for the operation of large high-speed aircraft (Tu-104, Il-18), since their strength turned out to be insufficient. Furthermore, the dimensions of old concrete runways were small for the new aircraft, the takeoff and landing run length of which was considerably increased in comparison with aircraft of the Li-2, Il-14 type.

Later stronger concrete coverings began to be used. Initially an increase in their strength was provided only by an increase in the thickness of the concrete slabs from 10-14 to 14-22 cm and the sides of the hexahedral slabs to 1.5 m. Such coverings were also laid out by hand with the use of small mechanization means. During subsequent years for the building of airfields there appeared domestic concrete-laying machines, which made it possible to completely mechanize the construction of concrete

coverings. In this case it was necessary to forego the hexahedral slabs and to change to slabs of rectangular form, the application of means of mechanization for the laying of which is considerably simpler. However, concrete coverings possess a number of substantial shortcomings, which will be examined below. Therefore the further improvement of rigid airfield coverings occurred because of the change in their construction.

Reinforced concrete coverings - the first stage of improvement of concrete coverings. They already had extensive application for airfields designed for medium and heavy loads. Still more improved are prestressed concrete and reinforced-concrete coverings. Thus far they are used in limited volume due to some technological difficulties of their construction.

Rigid coverings, being assembled from prestressed reinforced-concrete slabs, manufactured at plants of reinforced-concrete products, have large prospect. The prefabrication of slabs ensures their high quality. At the site there is accomplished only the installation of slabs, as a result of which the periods of reconstruction or erection of RW are sharply reduced.

At the present time at many plants there is mastered the series manufacture of prestressed slabs for precast coverings and the volume of their use on airfields grows with every year.

On several airfields, on which aircraft of the Tu-114 type operate, durable reinforced-concrete coverings were applied. However, there is no wide prospect for their future use, since they are substantially inferior with respect to their technical and economic and operational indexes to coverings made of prestressed concrete and reinforced concrete.

## § 22. GENERAL POSITIONS

The type and construction of airfield coverings are designated on the basis of the technical and economical comparison of variants taking into account the class of the airfield, its purpose and the magnitude of standard load (Table 26); the climatic, hydrogeological and soil conditions of the building area; the proposed intensity of operation; the concentration and directivity of motion and features of the effect of the aircraft being proposed for operation on the coverings; the presence of local building materials.

Table 26

Category of standard load	Magnitude of standard load on strut, t	Pressure in pneumatic tires, kgf/cm <sup>2</sup>	Type of main strut
I	70	10	Four-wheeled
II	55	10	
III	40	10	
IV	30	10	Single-wheeled
V	8	6	
VI	5	4	

- Note. 1. The distances between the pneumatic tires of conditional four-wheeled strut are taken equal to 70 and 130 cm.
2. The requirement for planning standard loads of III-IV category can be established as single-wheeled, equal to 17 and 12 t respectively, and pressure in pneumatic tires for V and VI categories of load - equal to 8 kgf/cm<sup>2</sup>.

The recommended constructions of coverings depending on the category of standard load are given in Table 27.

The rigid types of coverings can be constructed in all road-weather zones on sections with hydrogeological conditions of I-II types according to the classification of hydrogeological conditions given in Table 20. Rigid coverings are not used in the III type hydrogeological conditions.

Table 27

Type of covering	Category of load					
	I	II	III	IV	V	VI
	Recommended constructions					
Cast in-situ prestressed	+	+	+	-	-	-
Reinforced-concrete	+	+	+	+	+	-
Precast from prestressed ferroconcrete slabs (plant manufacture)	-	+	+	+	+	-
Concrete	-	-	-	-	+	-

- Note. 1. The + sign signifies the advisability of the use of constructions; the - sign inadvisability.
2. For I-II categories of standard loads it is permitted to use ordinary ferroconcrete coverings. On swelling and settled soils ordinary ferroconcrete coverings can also be used for the lower categories of standard loads.
3. The use of cast in-situ prestressed coverings is most advantageous on straight sections with length not less than 500 m.
4. Coverings made of precast prestressed slabs of plant manufacture primarily should be used: on sections subjected to nonuniform swelling or to settling; with necessity of building of coverings in shortened periods; on sections where concrete-laying machines cannot be effectively used; with necessity of building coverings at temperatures below the freezing point.
5. With calculated intensity of operation of covering not exceeding 1000 taxiings of the calculated aircraft per annum, concrete coverings can be used also for the IV category of standard loads.

When building rigid coverings on sections with III type of hydrogeological conditions there are provided the corresponding engineering measures (drainage, lowering of the level of ground water, erection of embankments) for the purpose of bringing the available conditions to the II type.

The minimum rise of the bottom of the trough during the construction of rigid coverings above the level of ground water and vadose water in all cases should be not less than that given in Table 28.

Table 28

Soil of natural base	Climate zone			
	II	III	IV	V
	Rise of the bottom of trough, m			
Medium sand	0.8	0.7	0.6	0.5
Fine sand and sandy loam	1.3	0.9	0.9	0.8
Silty soils, silty and light loams	2.0	1.6	1.5	1.4
Heavy loams, clay	2.0	1.5	1.2	1.1

With such rises the role of capillary rise of ground water to additional moistening of bases is considerably lowered.

Rigid coverings, as a rule, are placed on artificial bases made from materials treated with organic and inorganic binding agents. Soil-sand-cement bases for cast in-situ coverings are taken constant, equal to 20 cm.

With the IV-VI categories of standard loads and intensity of operation up to 1000 takeoffs and landings of the calculated aircraft per annum the bases can be constructed from untreated materials, in this case the construction of sand bases is allowed only in the I type of hydrogeological conditions.

Between the slabs and base in cast in-situ rigid coverings there are provided dividing layers of bituminized paper, grease-proof paper, a plastic film or sand-bitumen mixture. With roughness of the base exceeding 20 mm, furthermore, there should

be installed an evening sublayer of sand cement or sand asphalt.

With the construction of coverings from precast prestressed ferroconcrete slabs, being placed on all types of artificial bases, except sand, there is provided an evening sublayer of sand-cement mixture 2-4 cm thick. The dividing layer in this case is not necessary.

With change of temperature and moisture in cast in-situ rigid coverings there appear tensile, compressive and bending stresses, which cause the cracking of slabs. For reduction of these forces and prevention of cracking the concrete, reinforced concrete and ferroconcrete coverings are divided into separate slabs with longitudinal and transverse seams. As a rule, the longitudinal and transverse seams of the coverings in the slab intersect at right angles. With the laying out of seams staggered or with their displacement in the plan there is observed cracking in the direction of the adjacent transverse seams in the form of corners splitting off. Such failures appear as a result of temperature strains and large friction forces in the seams.

The longitudinal and transverse seams, which form standard rectangular slabs, are laid out according to the type of compression joints or the type of expansion joints. The compression joints make it possible for the slabs to reduce their dimensions, i.e., be compressed during shrinkage of the concrete in the process of its hardening and with temperature drop. The expansion joints are the clearances between adjacent slabs, the width of which ensures the freedom of movement of slabs during expansion, with temperature rise or with increase in the moisture of concrete. The maximum distances between the transverse compression seams in concrete and ferroconcrete coverings are taken according to Table 29.

Table 29

Type of covering	Thickness of covering, cm	
	Less than 26 cm	More than 26 cm
	Distance between seams, m	
Concrete	5	7
Ferroconcrete	25	30

The recommended maximum distances between the compression joints in reinforced concrete coverings for different climate zones are given in Table 30.

Table 30

Type of covering	Thickness of covering, cm			
	16-18	20-22	24-26	28-30
	Less than 26 cm			
II	20	20	20	20
III	20	25	30	35
IV	20	25	30	35
V	20	25	30	35

In cast in-situ prestressed coverings no compression joints are installed.

Longitudinal seams in all types of coverings are combined with technological joints.<sup>1</sup> In concrete coverings the distance between longitudinal seams is equal to 3.5-7 m.

<sup>1</sup>The construction of technological joints is stipulated by the width of coverage of the concrete-laying machines.



When laying concrete, when the free-air temperature is above  $+10^{\circ}\text{C}$ , the distances between the transverse expansion joints for all types of rigid coverings, except precast from prestressed ferroconcrete slabs, are equal to 60-100 m. At lower temperatures the distances between the expansion joints are taken as for the compression joints. In this case in reinforced concrete and ferroconcrete coverings no compression joints are constructed. In precast coverings expansion joints are installed every 20-25 m in both directions. In two-layered concrete coverings the distances between the transverse compression joints can be increased to 10 m, no expansion joints are installed in this case.

In all seams, as a rule, butt joints are provided: pin, matching, etc. The parameters of pin butt joints are given in Table 31. Sometimes instead of the construction of butt joints there is performed strengthening of the edge sections of slabs by reinforcement according to the recommendations of Table 32 or the thickening of these sections. In transverse expansion joints there is recommended the construction of slabs under the joint. The construction of seams without butt joints or without strengthening of the edge sections is allowed only for longitudinal seams of cast in-situ prestressed coverings with biaxial compression.

Table 31

Thickness of covering, cm	Diameter of pin, mm	Length of pin, cm	Distance between pins, cm	
			In through joints	In dummy joints
20 and less	20	40	30	40
22-30	25	30	50	40

Table 32

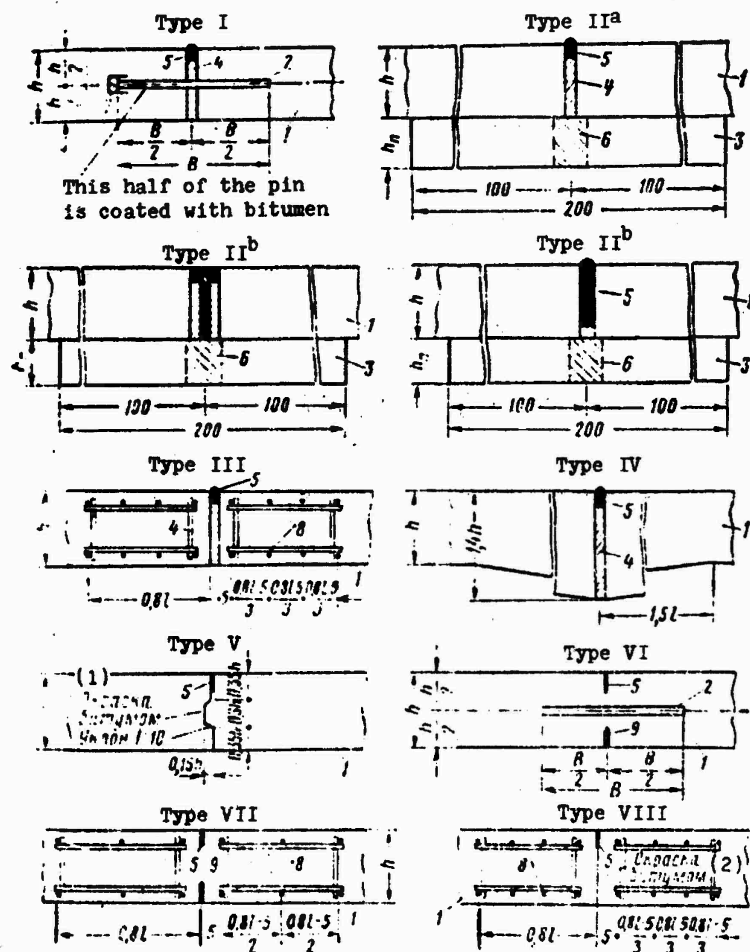
Thickness of slabs, cm	Quantity of reinforcement rods of class A-II in each cross section zone of the slab, pieces.	
	In through joints	In dummy joints
20	4 $\varnothing$ 12	3 $\varnothing$ 12
22	4 $\varnothing$ 12	3 $\varnothing$ 12
24	5 $\varnothing$ 12	4 $\varnothing$ 12
26	4 $\varnothing$ 14	3 $\varnothing$ 14
28	5 $\varnothing$ 14	4 $\varnothing$ 14
30	5 $\varnothing$ 14	4 $\varnothing$ 14

The constructions of seams of cast in-situ rigid coverings are given on Fig. 31, and recommendations regarding their use are given in Table 33.

The required thicknesses of structural layers of airfield coverings are determined by calculation. The minimum permissible thicknesses of coverings are given in Table 34.

The thickness of single-layer rigid coverings, as a rule, should not exceed 30 cm. When according to calculation large thickness is necessary, more effective constructions of coverings with respect to bearing capacity, durable bases or two-layered coverings are necessary. Two-layered coverings are constructed by the method of adding on a separating layer. As separating layer there is used grease-proof paper and other rolled materials, laid in two layers, or a layer of sand-bitumen 0.5-1.0 cm thick. It is advantageous to make the bottom layer of the two-layered covering from concrete, keramzit, sand and slag concrete. In the top layer prestressed ferroconcrete and reinforced concrete can be used. The mutual arrangement of the slabs of the upper and bottom layer should be such in order to avoid the matching of joints as much as possible.

The recommended constructions of coverings for the reinforced sections of verges are given in Table 35.



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Table 33

Type of seams	Construction of seams	Recommendations regarding use	
		In longitudinal seams	In transverse seams
I	Expansion seam with pin joint.	-	For all types of coverings except prestressed.
II-a	Through expansion joint with slab under seam.	-	For reinforced concrete and ordinary ferroconcrete coverings.
II-b, c	Through expansion joint with slab under the joint.	-	For cast in-situ prestressed coverings.
III	Through expansion joint with reinforcement of edges of slabs.	For reinforced concrete and ferroconcrete coverings at the points of intersection and adjoining to different constructions or other types of coverings.	For concrete coverings, and also ferroconcrete coverings, placed on swelling or settled soils; at points of intersection and adjoining to different constructions for all types of coverings, except prestressed.
IV	Through expansion joint with thickening of the edges of slabs.	For concrete coverings at the points of intersection and adjoining to different constructions and other types of coverings.	
V	Matching compression joint	For all types of coverings with thickness of slabs more than 20 cm.	-
VI	Dummy compression joint with pin connection	For concrete coverings	For all types of coverings except prestressed

Table 33 (Cont'd.)

VII	Dummy compression joint with pin connection	For concrete coverings	-
VIII	Through compression joint with reinforcement of edges	For all types of coverings (except prestressed with biaxial compression) with thickness of slabs 20 cm and less, and also for concrete and ferroconcrete coverings of any thickness with construction on swelling or settled soils.	For concrete coverings in technological joints.

- Notes.
1. In type II joints the thickness of the slab under the joint  $h_n$  is taken equal to 15 cm with thickness of the covering slab  $h < 20$  cm and 20 cm - with  $h > 20$  cm.
  2. The total weakening of the cross section in joints of types VI and VII should be not less than  $1/4 h$ .
  3. The pin in a joint of type VI is painted with bitumastic on the entire length.
  4. In the joints of types III, IV, VII and VIII  $l$  - the elastic characteristic of the covering slab (cm).
  5. In prestressed coverings with biaxial compression the longitudinal seams are made through without joints and additional reinforcement of edges.

Table 34

Covering	Thickness, cm
Prestressed ferroconcrete	14
Reinforced concrete, concrete and ordinary ferroconcrete	16

Note. The thickness of the structural layer of prestressed ferroconcrete with biaxial compression with laying of transverse fittings in channels should be not less than 18 cm.

Table 35

Covering	Sections of verges adjacent to the ends of RW					Reinforced sections of verges of RD, MS and ramps				
	Category of standard load									
	I	II	III	IV	V	I	II	III	IV	V
	Recommendations regarding use									
Cast in-situ concrete covering of precast concrete and ferroconcrete slabs	+	+	-	-	-	+	+	+	-	-
Asphalt-concrete made of mixtures of medium-grained and increased crushed stone.	-	-	+	+	-	+	+	+	-	-
Stone materials and soils, treated with organic and inorganic binding agents.	-	-	+	+	+	+	+	+	+	+

Note. With the construction of coverings from the local soils, treated with different binding agents, a necessary condition is the construction of protective layers. On airfields being designed for standard load of III-V category there is allowed the construction of soil-cement coverings without a protective layer with the necessary impregnation with organic binding agents and with emulsions.

### § 23. MATERIALS FOR COVERINGS

For the construction of rigid coverings there should be used cement-concrete, which conforms to requirements GOST 8424-63 "Road Concrete." The recommended brands of concrete according to compressive and tensile strength during bending are given in Table 36.

Table 36

Purpose of concrete	Rated brand for strength	
	During compression	Tension with bending
Single-layer coverings and top layer of two-layered coverings	$\geq 300$	$\geq 45$
Bottom layer of two-layered coverings, bases under asphalt-concrete coverings and for slabs under joints.	$\geq 250$	$\geq 35$
Anchor slabs of cast in-situ prestressed coverings.	$\geq 300$	-

For the bottom layer of two-layered coverings and bases under asphalt-concrete coverings, and also for heat-insulating layers there can be used sand concrete, keramzit concrete and slag concrete on porous blast-furnace slags.

Rigid airfield coverings can be reinforced with rod, wire and spun reinforcements. The type and class of reinforcement depend on the type of covering and the purpose of reinforcement in the construction. As tensioned reinforcement it is recommended to use hot-rolled reinforcement bar of indented shape of class A-IV (GOST 5781-61); high-strength binding wire of indented shape of class B<sub>p</sub>-II (GOST 8480-57): reinforcement strands (ChMTU/TsNIChM 426-61); high-strength smooth binding wire of class B-II (GOST 7348-55) in the form of bundles with tension to the hardened concrete.

As unstretched reinforcement there is recommended hot-rolled reinforcement bar of indented shape of class A-II (GOST 5781-61), and for reinforcement of uniaxially compressed slabs of precast coverings also cold-drawn ordinary smooth binding wire of class B-I (GOST 6727-53).

As installation, distribution, and structural bars and for elements of butt joints there is advisable hot-rolled smooth reinforcement steel of class A-I (GOST 5781-61); ordinary cold-drawn binding wire of class B-I (GOST 6727-53).

As tensioned reinforcement there is allowed reinforcement steel of class A-IIIv (GOST 5781-61), reinforced by drawing.

For the construction of bases under main coverings there can be used crushed stone, gravel, sand-gravel, soil-gravel and earth-crushed rock mixtures, local soils, rotten stone, shellrock, sand, and also acid and basic blast-furnace slags. All materials should satisfy the requirements expounded in the Technical specifications of the production and acceptance of airfield construction operations SN 121-60.

For filling the joints of rigid coverings there can be used: rubber-asphalt binding agents (RBV), "Izol" mastic, rolled moisture-proof izol, poroizol, TsN-2 mastic and other materials, having undergone production testing and having shown positive results.

#### § 24. CONCRETE COVERINGS AND VARIETIES OF THEIR CONSTRUCTIONS

Concrete coverings at the present time are the most widespread at airports of the USSR. The simplicity of construction and technology of construction provided them wide application, in spite of a number of significant shortcomings.

Concrete is one of the most widespread building materials, utilized in all areas of building. It is distinguished by high strength and density, sufficient frost and weather resistance. In general-construction practice the mechanical strength of concrete is characterized by the compression strength (brand of



concrete). However, as noted above, the material from which rigid type coverings are constructed should handle bending, and consequently absorb compressive and tensile stresses. Therefore the mechanical strength of concrete for coverings is characterized also by the ultimate tensile strength during bending.

The ultimate strength is determined by the testing of control samples of concrete, which were stored after manufacture at a temperature of about  $+15^{\circ}\text{C}$  and relatively high humidity for 28 days. For compression tests there are manufactured concrete cubes  $20 \times 20 \times 20$  cm, while for bending tests - concrete beams  $15 \times 15 \times 60$  cm.

A feature of concrete as a building material is the considerable difference of its compression strength and bending-tensile strength.

Since the slabs of concrete coverings under the action of operational loads and natural factors handle bending, tension and compression, the determining characteristics of airport concrete are the ultimate bending and tensile strength. This circumstance leads to the fact that the high compression strength of concrete in the construction of the covering is not used, but there is used the ability of concrete to absorb bending and tensile stresses, which is 8-12 times lower than the ability of concrete to absorb compressive stresses.

Besides this, it is necessary to consider the fact that after laying the concrete gathers strength gradually, in the first days it is insignificant, and the natural factors which cause internal stress in concrete are already in effect. Temperature and shrinkage stresses are the most dangerous for concrete during the hardening period. The greater they are, the larger the dimensions of concrete slabs in the plan. Therefore it is

necessary to restrict the dimensions of slabs so that the internal stresses appearing in them would not reach values dangerous for the strength of concrete.

The specifications of the designing of airport coverings (SN 120-60) determine that concrete coverings are constructed, as a rule, from rectangular slabs with ratio of the dimensions of sides within 1:1-1:1.5. The maximum size of the side of the slab should not exceed 5-7 m. Thus, the concrete covering is divided into separate slabs with longitudinal and transverse seams. The construction of the seam has great significance for the bearing capacity and service life of the covering. The experience of building and operation of rigid coverings shows that with the unsuccessful construction of joints they are precisely the source of progressing failures of the entire covering on the whole.

In concrete coverings we construct compression joints and expansion joints. The compression joints are constructed with clearance. The clearance in them is formed subsequently during the compression of slabs. The compression joint can be through with a thin lining of rolled material (grease-proof paper, izol and others). The most common are compression joints in the form of dummy joints, for which the slab is cut through on top to  $1/3$  the thickness. With the appearance of dangerous temperature or shrinkage tensile stresses in the slab its rupture occurs along this weakened section and the dummy joint is converted into a compression joint. The distance between the compression joints is determined by the dimensions of the slabs of this concrete covering.

The expansion joints are constructed with clearance. The width of the expansion joints is greater, the greater the distance between them. The expansion joints can simultaneously fulfill the role of compression joints, but the compression joints

cannot fulfill the role of expansion joints. The transverse expansion joints should be located from one another according to the requirements expounded in § 22.

Longitudinal expansion joints, as a rule, are not constructed on runways. All longitudinal seams are set up according to the type of compression joints. Only in individual exceptional cases, under very adverse climate conditions, can longitudinal expansion joints be applied on RW and soil MS.

Both the compression joints and expansion joints should be waterproof. In the process of operation of the covering the width of the joints is constantly changed, therefore to fill them material is necessary which has sufficient elasticity and maintains watertightness of the joint during the calculated changes in its width.

At the present time for the filling of joints in concrete coverings there are used "Izol" mastic and rubber-asphalt binding agent, which correspond to the above-indicated requirements to the greatest degree.

Around the joints are formed edge and corner sections, the strength of which is lower than the strength of the middle fields of the slabs. In order to raise the strength of edge and corner sections of slabs and to bring it to the strength of the middle fields in the joints between slabs we use butt joints. Butt joints somewhat unload the edge or corner sections of slabs from the load being transferred on them from the aircraft wheels, transferring part of it through the joint to the adjacent slabs. The most common are pin butt joints, in which the load from one slab is transferred to the adjacent with the aid of metal pins.

## § 25. REINFORCED CONCRETE COVERINGS

Reinforced concrete coverings include those in which the percentage of reinforcement is less than the minimum provided for ferroconcrete slabs. In reinforced concrete sections at calculated loads the tensile stresses are absorbed both by the reinforcement and by the concrete. The reinforcement of concrete coverings substantially increases the service life and stability of their operation under the action of repeated moving loads because of the decrease in the quantity of joints, and also the strengthening of the top layer by reinforcement bar. The presence of reinforcement prevents the opening of cracks, caused by moving loads and by temperature variations, in consequence of which the high operational qualities of coverings are ensured.

Reinforced concrete coverings are reinforced by lattices made of rod reinforcement of class A-II, with diameter 10-14 mm. The mesh is located in the upper zone of the section of coverings at a distance from the surface equal to  $1/3$  the thickness of the slab.

The coefficients of longitudinal reinforcement of slabs are taken from Table 37. The spacing of the longitudinal rods is taken within 15-30 cm.

The transverse reinforcement is structural. The distance between the transverse rods is taken as the following: 40 cm with thickness of slab up to 22 cm; 30 cm with greater thickness of slabs.

It is recommended to take the transverse and longitudinal rods of the mesh of the same diameter.

Table 37.

Distance between compression joints, m	Coefficient of longitudinal reinforcement of slab, m
20	0.15
25 and more	0.17
30	0.21
35	0.25

## §26. FERROCONCRETE COVERINGS

In ferroconcrete coverings the reinforcement is designed for the absorption of the forces which appear in slabs from the effect of operational loads. For the same load the thickness of the ferroconcrete slab is less than for concrete or reinforced concrete, but the consumption of reinforcement considerably increases. Besides this, as experience shows, ferroconcrete coverings are insufficiently reliable under the intense action of calculated operational loads. Therefore they are now used in exceptional cases and cannot be considered as promising.

For the reinforcement of ordinary ferroconcrete coverings there is used reinforcement 12-16 mm in diameter in the form of mesh and frames. The reinforcement is placed in longitudinal and transverse directions in the upper and lower zones of the section of the slab. The necessary area of the reinforcement is determined by calculation. The minimum reinforcement factor - 0.25. The distance between rods is designated within 10-30 cm depending on the required area of reinforcement and the taken rod diameter. In designing one should use the minimum quantity of different rod diameters.

Reinforcement mesh and framework are welded by the contact method. The butting of reinforcement mesh and individual rods

is accomplished in accordance with the recommendations of § 11 and Appendix III SNiP II-V, I-62.

The magnitude of the protective layer for all types of coverings is taken equal to 4 cm on the upper reinforcement and 3 cm on the lower reinforcement.

#### § 27. CAST IN-SITU PRESTRESSED COVERINGS

Cast in-situ prestressed coverings include those for which during construction there is accomplished preliminary compression of concrete. The compressive stresses prevent the emergence of tensile stresses from operational loads. This makes it possible to transfer considerably greater tensile stresses to the construction than to concrete coverings.

Coverings made of cast in-situ prestressed reinforced concrete possess high resistance to cracks because of the good resistivity to tensile and bending stresses; we do not fear a small crack opening in concrete of the extended area, since under the action of preliminary compressive stresses they are closed after the removal of load; they make it possible to reduce the thickness of covering 1.5-2 times in comparison with ordinary ferroconcrete coverings because of the use of high-strength reinforcement bar and concrete of high grades; they can be constructed from large slabs, which sharply reduces the number of joints and thereby improves the operational qualities of the covering. Some varieties of prestressed coverings can not have expansion joints at all. Advantages of cast in-situ prestressed coverings are most clearly manifested during the operation of large aircraft.

The type of prestressed covering should be selected taking into account the climate and hydrogeological conditions of

location of the airport, the dimensions and configuration of the section of the covering being created, the presence of local building materials. Under severe climate conditions it is advantageous to construct coverings with stressed reinforcement by high-strength steel reinforcement. In mild climate for the creation of prestressing in longitudinal direction there can be used the method of compression without reinforcement with the aid of power joints.

The sections of the coverings with length less than 500 m are advantageously constructed with tension of reinforcement to the hardened concrete. With the length of section 500 m and more there can be constructed longline tensioned concrete and prestressed coverings compressed without reinforcement.

#### § 28 PRESTRESSED COVERINGS WITH TENSIONING OF REINFORCEMENT TO HARDENED CONCRETE

For the reinforcement of this type coverings we use beams or strands of high-strength cold-drawn wire, or rods made of high-strength low-alloy hot-rolled steel (Fig. 32).

The reinforcement is installed before concreting. Its adhesion with the concrete is prevented, as a rule, because of the use of metal corrugated pipes, into which the reinforcement is passed. With reinforcement of the covering in transverse direction in the process of concreting with the aid of metal rods, hoses and other similar objects in the slabs are constructed channels, through which the reinforcing beams or rods are pulled after the setting of the concrete.

The prestressing in coverings is created after the concrete acquires the designed strength by means of the stretching of reinforcement by hydraulic jacks, set into the vertical sides of

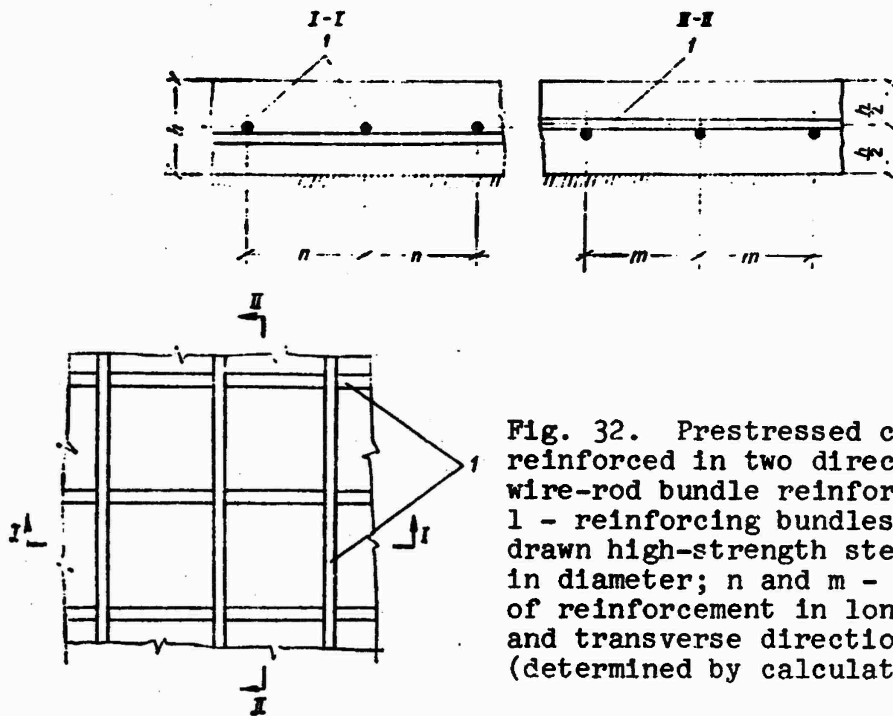


Fig. 32. Prestressed covering, reinforced in two directions by wire-rod bundle reinforcement: 1 - reinforcing bundles of cold-drawn high-strength steel 5-8 mm in diameter;  $n$  and  $m$  - spacing of reinforcement in longitudinal and transverse directions (determined by calculation).

slabs, with subsequent anchoring of this reinforcement in stressed state (Fig. 33).

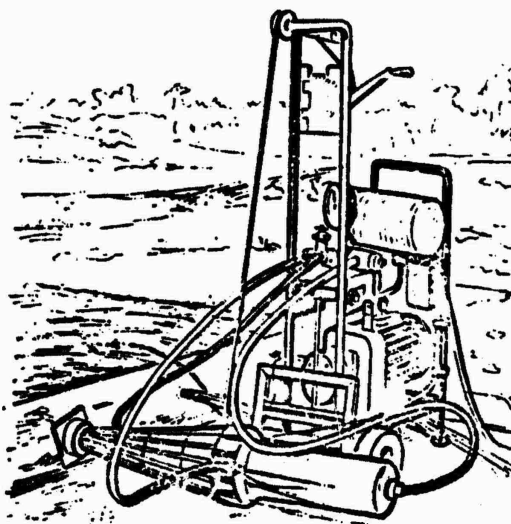


Fig. 33. Tension of the wire-rod bundle reinforcement of the covering by a hydraulic jack.



The method of tensioning of reinforcement to the concrete makes it possible to accomplish the stepped application of prestressing, which it is advantageous to do during the construction of coverings in order to remove from the slabs, which still have insufficient strength, shrinkage and temperature stresses and to reduce the losses of prestressing, which occur due to shrinkage and creep of the concrete.

A technological shortcoming of this type coverings is the difficulty of mechanization of construction and a greater quantity of manual operations during assembly and insulation of the reinforcement and its stepped tension and anchoring. Besides this, with tension of reinforcement in the channels of the solidified concrete, if the straightness of these channels is even insignificantly disturbed, there occur large losses of prestresses due to friction between reinforcement and the walls of channels, which sometimes reach 20-40%, which is equivalent to the loss of a corresponding amount of reinforcement bar.

With biaxial reinforcement with tensioning of reinforcement to the concrete the thickness of the covering should be not less than 18 cm, while with reinforcement in only one direction - not less than 16 cm. The maximum length of channels is restricted to 50-70 m, since with greater length the losses of prestresses due to friction strongly increase. Therefore through the indicated gaps in the covering it is necessary to provide technological breaks, and consequently expansion joints. The dimensions of the technological breaks should provide for the placement of jacks in them for tensioning of the reinforcement and anchor devices. The technological breaks, being filled up after the termination of operations by ordinary concrete, disturb the evenness of the covering, which is also one of the shortcomings of this type covering.

High-strength wire for the manufacture of bundles of reinforcement or strands intensely corrodes without special protection. Therefore a mandatory technological operation is the injection of channels with cement mortar, for which in the construction there are provided attachments for the connection of mortar pumps to the channels (Fig. 34), ensuring the exit of air from them when filling with mortar. With the reinforcement of coverings with hot-rolled rod reinforcement 14 mm and more in diameter the injection of channels is not compulsory. In this case the reinforcing rods before laying in the channels are coated with corrosion inhibitor.

If the reinforcement must be arranged perpendicular to the direction of concreting, it is difficult to place it within limits of the slab. There is a constructive solution of the covering, the stressed reinforcement in which is extended beyond the cross section of the slabs into the base or into the underlying soil. This provides certain technological advantages, since in this case there is the possibility of laying the reinforcement in the planned position before the beginning of concreting, and channels are not constructed in the slabs. However in this case it is necessary to additionally provide the construction of special supports in the edge slabs for transverse reinforcement or under the end sections of slabs for longitudinal reinforcement, and also its reliable anticorrosion protection in the soil.



Fig. 34. Mortar pump for injection of the channels of wire-rod bundle reinforcement.

The stressed reinforcement, extended beyond the slabs of the covering, creates a bending moment in them, which under some conditions can disturb the longitudinal stability of the covering on the whole. Therefore when designing such a covering it is necessary to try to provide the minimum amount of eccentricity of compressive force, to place the reinforcement as close as possible to the bottom of the slabs. The bending moment appearing from the eccentric application of compressive force should be damped with reserve by the stabilizing effect of the slabs own weight.

Prestressed coverings with tensioning of reinforcement to the solidified concrete are sufficiently general-purpose and can be constructed at different sites. The method of tensioning of reinforcement to concrete at the present time is advisable with compression of the cast in-situ coverings of predominantly small size and compression of all varieties of coverings in transverse direction.

#### § 29 PRESTRESSED COVERINGS WITH TENSIONING OF REINFORCEMENT BEFORE CONCRETING

In 1956 in the Soviet Union there was developed a design of stressed cast in-situ longline tensioned concrete coverings (Fig. 35) and the method of their reinforcement. This type covering underwent production testing and is used for the building of airports.

In longitudinal direction the covering is reinforced with high-strength wire (or strands), being spread by a mechanized method on a section 500-1000 m long (Fig. 36). The tensioning of reinforcement is accomplished before concreting simultaneously on the entire length of the catching device. This ensures low specific labor input with spreading and tensioning of reinforcement and eliminates tensioning losses due to friction.

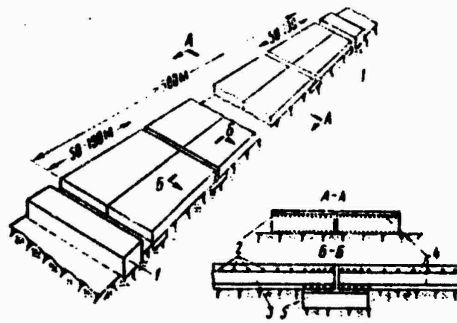


Fig. 35. Diagram of pre-stressed longline tensioned concrete covering: 1 - anchor; 2 - rods; 3 - covering; 4 - stays; 5 - slab under joint.

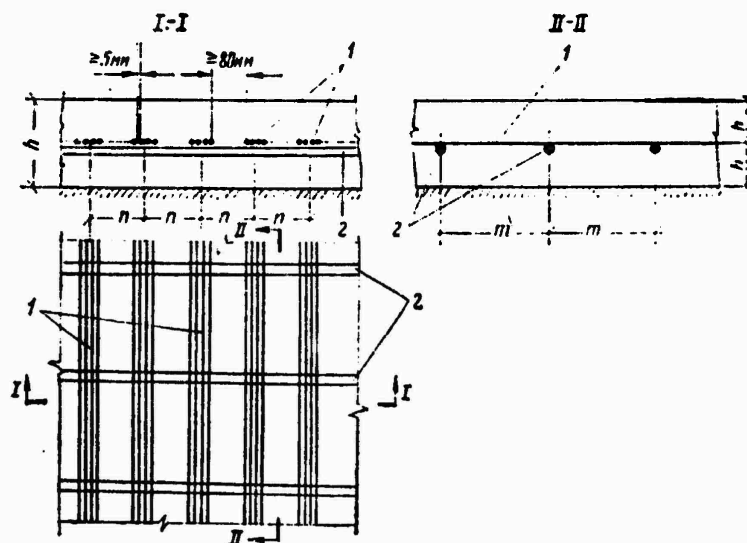


Fig. 36. Prestressed longline tensioned concrete covering: 1 - stays of cold-drawn high-strength steel of indented shape 3-5 mm in diameter; 2 - reinforcing bundles of cold-drawn high-strength steel 5-8 mm in diameter or plant-manufactured strands; n and m - spacing of reinforcement in longitudinal and transverse directions (determined by calculation).

Besides wire or strand reinforcement coverings of the considered type can be reinforced by rod hot-rolled low-alloy high-strength reinforcement of class A-IV with indented shape. With the aid of a self-propelled welder moving along road forms the separate reinforcing bars are joined on the spot with length equal to the distance between the anchor slabs. The bars are

joined in a length of the necessary length with threaded bushings, however the ends of the separate rods should have rolled thread, since with thread cut by the usual methods the effective cross section of the reinforcing rods is decreased.

For keeping the stressed reinforcement in tension for the period of concreting of the covering and for the concrete to reach the necessary strength we install anchors at the beginning and end of each section every 500-1000 m. Anchors are of the following types: underground in the form of sunk ferroconcrete walls; ground ferroconcrete slabs, entering the composition of the area of the covering being erected, being kept from displacement by friction forces, the necessary magnitude of which is reached with the aid of soil tamping; ground ferroconcrete slabs with width equal to the width of coverage of the concrete-laying machine, and with length equal to the width of the covering being erected, arranged across the covering being constructed. These anchor slabs also form the site of the covering and work under the action of horizontal shearing forces, being developed by the stressed reinforcement connected to them as continuous beams of the wall, lying horizontally, the displacement resistance is provided by spurs (Fig. 37), the depth of laying of which is determined by calculation.

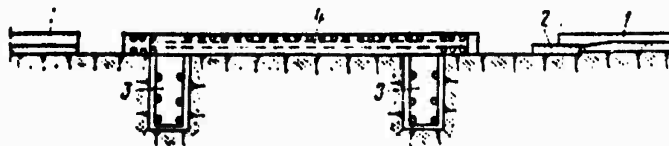


Fig. 37. Cross-sectional view of anchor slab: 1 - covering; 2 - slabs under joint; 3 - underground anchor; 4 - anchor slab.

For improvement in the conditions of transfer of prestresses to the concrete and reduction of its losses, which appear from friction of the underseam of the slab against the base, the

covering after the concrete gets the necessary strength is cut by transverse seams into slabs 50-100 m long. The strength of the corner and edge sections of the slabs at the transverse seams increases because of backing slabs under the transverse seams.

For coverings with tensioning of reinforcement before concreting the use of steel wire 3-5 mm in diameter with shaped surface or bar steel of indented shape makes it possible to manage without special devices for anchoring the reinforcement in concrete, since such reinforcement with tempering has the ability to be self-anchored. Therefore in longline tensioned concrete coverings the tempering of reinforcement is practically accomplished by its disconnection from anchor slabs and cutting in the transverse expansion joints.

The shortcomings of the examined method of tensioning of reinforcement include the impossibility of restoration of losses of prestressing, which proceed from creep of the concrete and relaxation of stresses in the reinforcement. Thus far there is no sufficiently verified information about the corrosion of wire reinforcement in the coverings working at operational load with the opening of cracks in the lower zone. Therefore such coverings still must be designed for prohibition of cracks which intersect the wire reinforcement, and in slabs to create a protective layer of concrete: in coverings with thickness up to 20 cm - not less than 4 cm, and in coverings with thickness more than 20 cm - not less than 5 cm.

In coverings with tensioning of reinforcement before concreting the reinforcement can be arranged in the manner most suitable for the operation of slabs under load. Therefore the stressed reinforcement in slabs should be placed in two layers, but with displacement of its overall center of gravity downward from the neutral plane to  $1/6$  the thickness of covering. This

will provide not only an increase of the useful height of the section of slabs, but it will facilitate more effective work of the concrete in the extended zone.

When designing coverings with the self-anchoring reinforcement being stretched before concreting special attention must be given to the effect of temperature-shrinkage stresses, which are developed in long slabs, and in the period of hardening of concrete before the transfer of prestresses to it can cause transverse cracks. The basic means of reduction of the indicated stresses is good care of the hardening concrete, which provides stability of the temperature-moisture conditions of coverings. On the surface of the freshly laid concrete there should be created a vapor-, water-tight film, and after termination of the setting of concrete it is necessary to cover the slabs with a heat-insulating layer of sand 10-15 cm thick, in which moisture above optimum should be constantly maintained. Care should be accomplished before the transfer of prestresses to the concrete.

When the stability of temperature-moisture conditions in the process of hardening of concrete cannot be provided or the distance between the expansion joints is more than 100 m, for the prevention of cracking of the covering constructive measures are specified - construction of dummy joints in the slabs every 20-25 m, which are metal diaphragms 1.5-2.0 mm thick, having grooves for longitudinal wire reinforcement. Since in the area of these joints corrosion of the reinforcement is possible, they are strengthened with metal pins, as in dummy joints of conventional coverings.

In the coverings, reinforced by stressed bar steel 20 mm and more in diameter, temperature-shrinkage cracks cannot lower the strength of the covering, since there is no danger of breaks of reinforcement due to corrosion in the areas of cracks, and the cracks themselves are reduced after the transfer of

prestressing to concrete, and in the covering solidity is restored.

§ 30. PRESTRESSED COVERINGS, COMPRESSED  
IN LONGITUDINAL DIRECTION BY THE METHOD  
WITHOUT REINFORCEMENT

For the creation of preliminary compressive stresses in the concrete without the use of stressed reinforcement there can be used different constructions of load-bearing joints. The most successful technical solution of such a covering was achieved by French engineers, who used flat jacks (Fig. 38) as load-bearing elements. For perception of the thrust being created by jacks, on the faces of the covering there are constructed thrust plates or other anchor systems.



Fig. 38. Flat hydraulic jack.

The coverings, in which longitudinal prestressing is created by flat jacks, are fixed type coverings, since regardless of the temperature, moisture and other changes the length of slabs remains practically constant, fixed by the position of the limit stops. Only the most extreme slabs have some possibility of insignificant displacements because of the elasticity of stops.

An advantage of fixed type coverings is the possibility of avoiding transverse expansion joints. The working joints



function only during the period of building, when prestressing is created, and then they become solid.

However the fixed system has a great shortcoming, since prestresses in such a covering depend on the temperature and moisture variations of the concrete. This shortcoming is not decisive when building coverings in areas where sharp seasonal temperature variations are absent. But for severe climate conditions of the majority of the areas of the Soviet Union the use of compression without reinforcement with the aid of flat hydraulic jacks is coupled with some difficulties. The magnitude of prestresses in the slabs, being compressed by the method without reinforcement, should be designated so that in the spring time the covering would have the calculated bearing capacity, and during the coldest period of the year the concrete should not experience tensile temperature stresses. Investigations show that with change of the mean temperature of slab by  $1^{\circ}\text{C}$  the prestresses in a fixed type covering are changed  $2.5-3.0 \text{ kgf/cm}^2$ . This parameter, which is the product of the coefficient of linear temperature expansion of concrete by its modulus of elasticity, is important for the correct establishment of the construction of the covering.

Flat hydraulic jacks can be located in load-bearing joints during the time when prestresses are created and restored. For the retention and fixing of thrust created by jacks in the joints are placed wedged locking devices. As experience shows, it is necessary to observe the load-bearing joints of coverings, being compressed by flat hydraulic jacks, and to compensate the losses of prestresses 1.5-2 years after the initial compression. After this period the load-bearing joints are made solid and the covering becomes practically seamless. The fixed type covering, compressed without reinforcement, with daily and especially with seasonal temperature and moisture variations experiences considerable changes in prestresses, which is a substantial

deficiency. For the purpose of softening the fluctuations of prestresses it is possible to use load-bearing joints with pressure regulation in flat jacks, or load-bearing joints having elasticity.

It is possible to regulate the pressure in jacks in stages: with lowering of temperature increase the pressure to calculated, and with rise of temperature reduce it to the prescribed value. Such stepped regulating can be expediently accomplished twice a year - spring and autumn. However in this case daily fluctuation of prestresses in the covering remain, and seasonal are smoothed to a considerable degree.

A good construction of elastic load-bearing joint can be permitted with the application of steel elastic constraints, which work under tension. The main parameter of the joint is the ratio of the length of elastic connection to the distance between the joints. The value of this ratio is affected by conditions of smoothing of the fluctuations of prestresses. In order to completely eliminate these fluctuations, it is necessary to make the length of the connection equal to the distance between joints, i.e., to change to solid stressed reinforcement of the covering. With complete absence of elastic connections we have a fixed type covering with the sharpest fluctuations of prestresses.

Calculations show that the optimum relationships between maximum and calculated prestresses for the examined constructions of load-bearing joints should be taken within 1.5-2.5.

#### § 31. COMPRESSION OF PRESTRESSED CAST IN-SITU COVERINGS IN TRANSVERSE DIRECTION

The method of transverse compression by wire-rod bundle or rod reinforcements, placed in the cross section of the covering

and stretched to the solidified concrete, is the most common. Transverse compression by such a method is laborious - it exceeds the labor consumption of longitudinal stressed reinforcement of longline tensioned concrete coverings 3-3.5 times.

Some improvement of the method of transverse stressed reinforcement of coverings can be achieved by the removal of transverse reinforcements from within the section of the covering slabs to the base. In this case the transverse reinforcement can be placed on the entire width of the covering before the beginning of concreting, and it is not necessary to install channels in the slabs for its arrangement. This makes it possible to break up with time the technological operations of transverse and longitudinal reinforcement, which provides a sharp increase in the rate of concreting.

In practice uniaxially compressed cast in-situ prestressed coverings with calculated unstressed transverse reinforcement can find wide application. A basic feature is the fact that the slabs of these coverings have different margin of resistance to cracks in longitudinal and transverse directions.

The bending moment, with which the crack resistance of compressed cross sections of slabs (which have only longitudinal preliminary compressive stress) is provided, will be

$$M_x^I = W R_{pn} + M_{oa}^I. \quad (32)$$

The longitudinal sections, which do not have prestresses, can take moment.

$$M_y^I = W R_{pn}, \quad (33)$$

where  $W$  - the resistance moment of the cross section of the slab,  $\text{cm}^3$ .

$R_{pn}$  - the tensile strength of concrete with bending,  $\text{kgf/cm}^2$ ;

$M_{06}$  - the moment of forces in the stressed reinforcement relative to the top core, kgf·cm.

Consequently, if we design a uniaxially compressed covering, calculating it for the prohibition of cracks with operational load, then the effect from prestressing in longitudinal direction will not be used, and the necessary thickness of the covering in this case will be the same as an ordinary concrete covering. But if we reinforce the transverse direction of uniaxially compressed slabs by the calculated unstressed reinforcement and allow as in ordinary reinforced concrete the limited opening of longitudinal cracks in unstressed concrete of the tension area, then it is possible to obtain a very effective construction of the airfield covering.

Such a covering with operational load will work with different rigidity of sections in longitudinal and transverse directions, i.e., it will possess orthotropism. Orthotropic slabs on an elastic base possess the ability to effectively redistribute internal forces, transferring a large part of them to more rigid directions and unloading the directions which possess lesser rigidity.

For determining the rigidity of unstressed ferroconcrete sections of the slab, working under load with the opening of cracks, V. I. Murashev's formula can be used

$$B = E_a W (h_0 - x), \quad (34)$$

where  $E_a$  - elastic modulus of reinforcement, kgf/cm<sup>2</sup>;

$h_0$  - the useful height of the section of slab, cm;

$x$  - the height of the compressed zone of the concrete of the slab, cm;

$W$  - conditional elasto-plastic moment of resistance of the section, equal to the moment of force in reinforcement

relative to the center of gravity of the compressed zone of concrete, divided by stress in the reinforcement,  $\text{cm}^3$ ;

By having the actual values of longitudinal and lateral rigidities of orthotropic covering, it is possible to determine the bending moments  $M_x$  and  $M_y$ . By the construction of the covering the following equality should be provided:

$$M_x = WR_{ps} + M_{os}; \quad (35)$$

$$M_y = F_a R_a (h_0 - 0.5x), \quad (36)$$

where  $F_a$  - the cross-sectional area of bottom reinforcement,  $\text{cm}^2$ ;

$R_a$  - calculated resistance of reinforcement,  $\text{kgf/cm}^2$ .

With transverse compression the longitudinal seams between slabs cannot have butt joints, since because of compression forces rather high friction forces are developed in them, which ensure the combined work of adjacent slabs under the action of operational loads. In coverings with uniaxial longitudinal prestressing in longitudinal seams it is necessary to provide butt joints for increase in the bearing capacity of the edge sections of slabs.

### § 32. COVERINGS OF PRESTRESSED FERROCONCRETE SLABS OF PLANT MANUFACTURE

Airfield coverings made of precast prestressed ferroconcrete slabs create the possibility of mass production of slabs by industrial methods at plants of ferroconcrete products and the conversion of the building site into assembling. In this case the necessity arises for subsidiary enterprises for storage and handling of initial building materials, the preparation of concrete and its transportation to the place of laying.

It is advantageous to use precast coverings if it is necessary to construct them in shortened periods or in winter conditions.

In the USSR there are developed, tested and applied several types of precast prestressed ferroconcrete slabs for coverings, and rational methods of their installation are also developed. The optimum construction for a precast airfield covering at the present time is a ferroconcrete slab, reinforced by biaxial double-row prestressed reinforcement. Such a slab provides the strength and resistance to cracks required for the coating with insignificant consumption of reinforcement bar. Slabs of ordinary reinforced concrete are irrational, since even with increase in the consumption of reinforcements 2-3 times they do not possess the necessary crack resistance and service life.

The dimensions of slabs should be the maximum permissible with respect to the technological capabilities of the equipment used for the transporting of slabs and the installation of covering. A number of conveyor and the majority of production-line plants are equipped only for uniaxial (longitudinal) stressed reinforcement of slabs. For mass-production at such plants there is developed the PAG-XIV slab with dimensions in plan  $2.0 \times 6.0$  m (Fig. 39), which is reinforced in longitudinal direction by double-row prestressed reinforcements of indented bar steel of class A-IV, and across - by ordinary unstressed reinforcement. Such a slab is orthotropic and has different rigidity of sections in longitudinal and transverse direction.

Longitudinal bar reinforcement is stretched by the electro-thermal method to rigid pallet-trucks before concreting.

If the equipment of the ferroconcrete product plant does not make it possible to make a slab 6 m long, then the dimensions of slabs are taken  $2.0 \times 4.0$  of brand PAG-III with scheme of reinforcement as plates PAG-XIV. The basic thickness of uniaxially

compressed slabs is 14 cm, but with insignificant conversion of available equipment at the manufacturers it is possible to manufacture slabs with thickness from 12 to 16 cm.

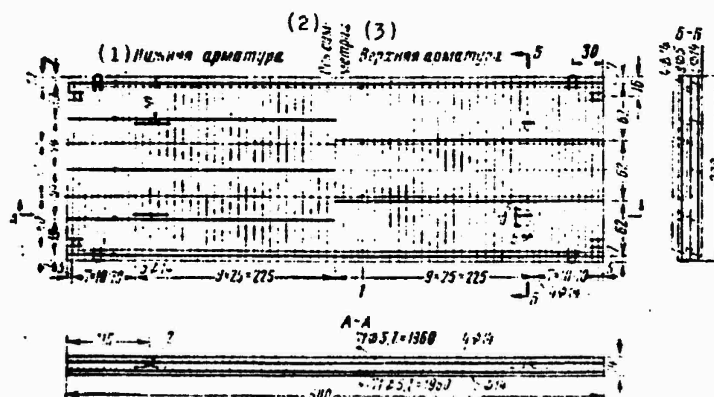


Fig. 39. Diagram of the reinforcement of slab PAG-XIV: 1 - distribution rods 5 mm in diameter;  $l = 5960$  mm; 2 - lifting loop 14 mm in diameter;  $l = 600$  mm.  
KEY: (1) Bottom reinforcement; (2) Axis of symmetry; (3) Top reinforcement.

For slabs reinforced with indented rod reinforcement we use concrete of brand 300. The transfer of prestressing to concrete is allowed with its strength not less than  $210 \text{ kgf/cm}^2$ .

At the present time for standard prestressed slabs for precast coverings of airports there are working drawings, approved by Gosstroy of the USSR, and the production of PAG-XIV slabs mastered by a number of ferroconcrete product plants. The general view of a precast covering is shown on Fig. 40.

Coverings of precast prestressed ferroconcrete slabs are designed on the basis of the same specifications which are presented to rigid cast in-situ coverings. For the most rational organization of mass production it is necessary that the slabs

released by industry have, as a rule, identical thickness and dimensions in plan.



Fig. 40. General view of the covering of precast prestressed PAG-XIV slabs.

To provide the necessary bearing capacity of this covering there are used artificial bases, the rigidity and thickness of which are designated by calculation taking into account the prescribed design load, hydrogeological and climate conditions, in which the airport is located.

### § 33. PRINCIPLES OF CALCULATION OF RIGID COVERINGS

Rigid coverings are calculated by the method of limiting states, accepted in the USSR for the calculation of building constructions. The limiting state - is such a state of construction, with the advent of which it becomes incapable of resisting external actions or obtains damage or deformations inadmissible with respect to operating conditions. The calculated limiting states are taken different for different types of rigid coverings.

With the appearance of cracks in concrete and reinforced concrete coverings their bearing capacity practically disappears. Therefore for such coverings the state, corresponding to the appearance of cracks as a result of the effect of load, is



the calculated and is characterized as the limiting state with respect to strength.

For compressed sections of prestressed coverings as calculated there is taken the limiting state with respect to cracking. However, taking into account that the cracks in such coatings do not represent practical danger for further operation and in the absence of load they are in tightly closed state, and the bearing capacity of coverings with the advent of cracks is by no means exhausted, the guarantees against their appearance during calculations are taken less than for concrete and reinforced concrete coverings.

In ferroconcrete coverings, reinforced by unstretched reinforcement, cracks are allowed in the stage of operation, but the width of their opening is limited. The calculated limiting states for such coverings are the limiting state with respect to strength, which begins when stresses in the stretched reinforcement reach its calculated resistance, and the limiting state with respect to opening of cracks, being characterized by their width, is equal to 0.3 mm.

The problem of calculation of the covering involves providing guarantees against the onset of some limiting state in it during the period of operation. At the same time for obtaining the economical solutions these guarantees should not be superfluous, i.e., it is necessary to see that the values of forces, which appear in the slabs of coverings, be close to the maximum permissible values.

In general form the basic condition of calculation by limiting states can be expressed by dependence

$$N_p \leq \Phi(m, k, R^n, S). \quad (37)$$

where  $N_p$  - force which appears in the covering slab from the calculated load;  
 $\Phi$  - function which characterizes the maximum permissible force;  
 $m$  - coefficient of the operating conditions of the construction;  
 $k$  - coefficient of the quality of materials;  
 $R^H$  - standard strength of materials;  
 $S$  - geometric characteristics of the section.

Since the limiting states of rigid coverings indicated above are caused by the action of bending stresses, the calculation is conducted for this form of forces. Taking this into account the basic condition of calculation can be written in the form:

$$M_p \leq M_{np}, \quad (38)$$

where  $M_p$  - calculated bending moment from external actions;  
 $M_{np}$  - maximum permissible bending moment for the section in question.

The calculation of coverings involves determining moments  $M_p$  and  $M_{np}$ , the divergence between which should not be more than 5%.

Since moments  $M_p$  and  $M_{np}$  depend on the construction of covering (its thickness, the quantity of reinforcement, amount of prestressing in concrete, type and thickness of artificial base), the calculations must be conducted by the method of successive approximations. The construction of covering is assigned and  $M_p$  and  $M_{np}$  are determined. If the divergence between them exceeds 5%, refine the construction of covering and again calculate. This is repeated until the values of  $M_p$  and  $M_{np}$  approach within 5%.

### The Determination of Calculated Bending Moments in Slabs of Rigid Single-Layer Coverings, Constructed on Sand Bases.

The slabs of rigid coverings are theoretically slabs of limited dimensions, lying on elastic bases and experiencing the effect of a repeated moving dynamic load from the aircraft wheels, and also temperature effects from uneven temperature distribution through the thickness of the covering. The precise calculation of such a construction is very complex. Therefore we resort to a number of simplifications, which considerably facilitate calculation, and do not substantially affect the accuracy of results. These simplifications are reduced to the following.

The calculation is performed on a static wheel load. The dynamicity of the effect of load is considered by the dynamic-response factor  $k_{дн}$  (Table 38), the value of which depends on the group of the section of coverings (Fig. 41).

Repetition of the application of load and temperature effects are considered by the complex coefficient of the operating conditions  $m$ , which also considers a number of factors. This coefficient is introduced into calculation when determining the limiting moment  $M_{np}$ .

Taking into account the relatively greater linear dimensions of the slabs used in building practice, with central loading they are considered as infinite. In this case the formulas for determining the calculated bending moments are considerably simplified.

The calculated bending moments with placement of the load on edge sections (near joints) are determined with the aid of transfer coefficients, obtained on the basis of theoretical calculations and confirmed experimentally.

Table 38. Values of coefficients

Group of sections of coverings	List of sections in the group	Overload factor $M_p$	Dynamic-response factor $k_{\text{дн}}$ , with pressure in pneumatic tires, $\text{kgf/cm}^2$			Coefficient of operating conditions of sections m				
			Up to 10 inclusively	11-15	Over 15	Concrete	Reinforced concrete	Ordinary ferroconcrete	Wire reinforcement and strands	Prestressed ferro-concrete, reinforced
A	Main RD, end sections of RW with length 150 m	1.0	1.2	1.25	1.3	0.8	0.9	1.0	1.0	1.1
B	Sections of RW with length $\frac{l}{4}$ - 150 m, adjacent to the end, auxiliary RD, MS, ramps and other similar areas of the flight lines	1.0	1.1	1.15	1.2	0.9	1.0	1.1	1.1	1.2
C	Middle part of the RW	0.85	1.1	1.1	1.1	0.9	1.0	1.1	1.1	1.2
D	Edge sections with respect to width in the middle part of the RW	0.85	1.1	1.1	1.1	1.1	1.2	1.3	1.3	1.4

Note. During the calculation of coverings made of precast prestressed ferroconcrete slabs increase the coefficient of operating conditions of sections by 20%.

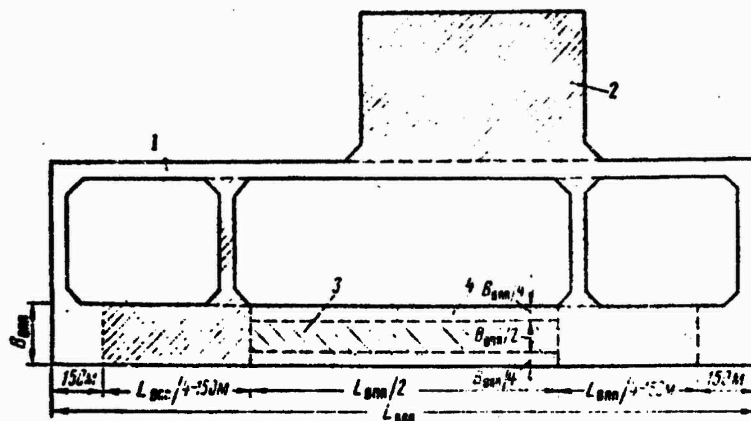


Fig. 41. Diagram of division of coverings into groups of sections: 1 - sections of group A; 2 - sections of group B; 3 - sections of group C; 4 - sections of group D.

With the aid of correction factors there is considered the redistribution (increase in one and decrease in the other direction) of bending moments in slabs of prestressed coverings with uniaxial compression. The redistribution of moments occurs because these slabs have different rigidity in longitudinal and transverse directions: in transverse direction there should not be cracks in the stage of operation, but in longitudinal direction they are allowed.

With the presence of several wheels on a calculated aircraft strut the calculation is performed for the action of each wheel individually and the forces are totaled, using the principle of independence and summation of the action of forces.

The properties of elastic base when determining bending moments are described by a certain calculated model. During the calculation of airfield coverings, as noted above, two calculation models are used: Winckler's model, characterized by one substratum coefficient; model of linearly deformable half-space, characterized by the modulus of deformation and Poisson's ratio. Recently

there is noted the tendency to use only one model - Winckler. According to this model the base is represented by a system of vertical springs not connected together; deformation of the surface occurs only at those points where the load is applied. As shown by the experimental studies conducted by L. I. Manvelov and E. S. Bartoshevich, this model corresponds the closest to the actual distributive properties of soil bases during the calculated period.

The calculated bending moments are determined in the following order.

1) We establish the position of the calculated section with central loading of the slab. With single-wheeled strut the section located under the center of the pneumatic tire impression is the calculated, while with multiwheel strut it is the section located under the center of impression of the pneumatic tire that is closest to the center of gravity of the strut (Fig. 42);

2) We determine the bending moment from the action of pneumatic tire, the center of impression of which coincides with the calculated section

$$M_1 = \kappa_{\Delta H} n_p P_H f(\alpha) \text{ kgf} \cdot \text{cm}, \quad (39)$$

where  $P_H$  - standard single-wheel load, kgf;  
 $\kappa_{\Delta H}$  and  $n_p$  - the dynamic-response and overload factors respectively, whose values are given in Table 38;  
 $f(\alpha)$  - the function whose values are given in Table 39, depending on the given radius of load

$$\alpha = \frac{R}{l}.$$

Here  $R$  - radius of the circle, equivalent to the area of impression of pneumatic tire, cm;

$l$  - the elastic characteristic of the slab, which is determined by formula

$$l = \sqrt{\frac{B}{C}}. \quad (40)$$

where  $C$  - calculated substratum coefficient of soil base, which it is recommended to determine according to data of field soil tests by test loads, and in their absence we use tabular values;

$B$  - rigidity of the calculated sections.

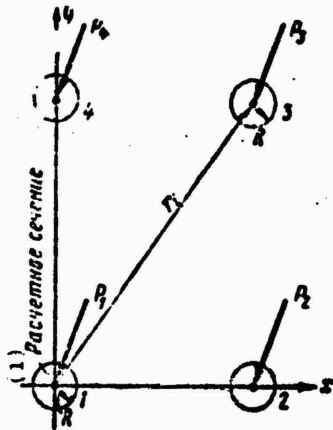


Fig. 42. Calculated diagram of the aircraft strut: 1, 2, 3, 4 - wheels of the aircraft strut;  $P_1, P_2, P_3, P_4$  - aircraft wheel load;  $R$  - radius of the circle equivalent to the area of impression of pneumatic tire;  $r_1$  - the distance between the centers of impressions of pneumatic tires.

KEY: (1) Calculated section.

3) We calculate the bending moments which appear in the calculated section from the action of the pneumatic tires, located outside this section

$$M'_{x(y)} = \bar{M}'_{x(y)} P_n. \quad (41)$$

where  $\bar{M}'_{x(y)}$  - unit bending moment in directions  $x$  and  $y$ .

The values of unit moments are given in Table 40 depending on the provided distance from the center of impression of the pneumatic tire to the calculated section

$$l = \frac{x}{r}, \quad y = \frac{y}{r}.$$

4) We find the maximum bending moment with central loading as the largest total moment being created by all wheels of the aircraft strut in the calculated section, perpendicular to axis "x," or "y."

$$M_{x(y)}^u = \kappa_{x(y)}(M_1 + \sum M_{x(y)}^l), \quad (42)$$

where  $\kappa_{x(y)}$  - coefficient which considers the redistribution of bending moments.

Table 39

$\alpha$	$f(\alpha)$	$\alpha$	$f(\alpha)$	$\alpha$	$f(\alpha)$	$\alpha$	$f(\alpha)$
0	0	0.26	0.1631	0.52	0.1204	0.78	0.0555
0.02	0.4209	0.28	0.1763	0.54	0.1171	0.80	0.0834
0.04	0.3555	0.30	0.1700	0.56	0.1139	0.82	0.0714
0.06	0.3188	0.32	0.1641	0.58	0.1108	0.84	0.0794
0.08	0.2921	0.34	0.1585	0.60	0.1079	0.86	0.0775
0.10	0.2714	0.36	0.1534	0.62	0.1052	0.88	0.0756
0.12	0.2545	0.38	0.1485	0.64	0.1027	0.90	0.0738
0.14	0.2402	0.40	0.1438	0.66	0.1004	0.92	0.0721
0.16	0.2278	0.42	0.1395	0.68	0.0971	0.94	0.0704
0.18	0.2169	0.44	0.1353	0.70	0.0946	0.96	0.0687
0.20	0.2072	0.46	0.1313	0.72	0.0922	0.98	0.0671
0.22	0.1984	0.48	0.1275	0.74	0.0899	1.00	0.0655
0.24	0.1904	0.50	0.1239	0.76	0.0877		

For prestressed coverings with uniaxial compression the values of  $\kappa_{x(y)}$  are given on Fig. 43. For other types of coverings it is taken as one.

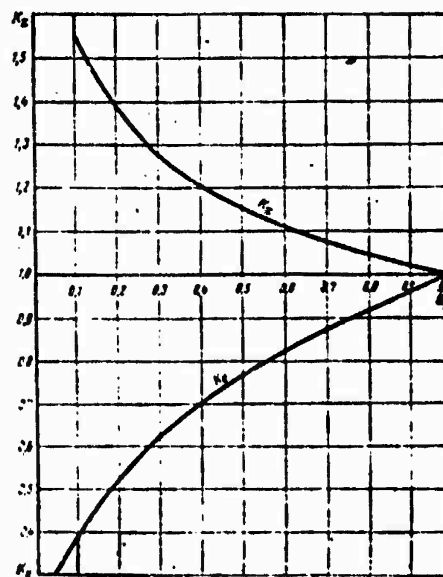


Fig. 43. Values of coefficients  $\kappa_x$  and  $\kappa_y$  depending on the rigidity ratio.



Table 40

$\omega(\%)$	0	0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.10	1.2	1.3	1.4	1.5
0	—	0.2587	0.1918	0.1283	0.0919	0.0667	0.0492	0.0338	0.0219	0.0126	0.0051	0.0011	-0.0058	-0.0098	-0.0132	-0.0155	-0.0174
0.05	0.3202	0.2578	0.2015	0.1241	0.0950	0.0647	0.0403	0.0315	0.0224	0.0128	0.0054	0.0011	-0.0058	-0.0098	-0.0132	-0.0155	-0.0174
0.1	0.2578	0.2410	0.1937	0.1323	0.1000	0.0745	0.0526	0.0355	0.0235	0.0136	0.0054	0.0011	-0.0058	-0.0098	-0.0132	-0.0155	-0.0174
0.2	0.1936	0.1754	0.1723	0.1330	0.0915	0.0725	0.0529	0.0358	0.0254	0.0149	0.0067	0.0013	-0.0018	-0.0098	-0.0128	-0.0150	-0.0170
0.3	0.1565	0.1469	0.1565	0.1192	0.0925	0.0707	0.0524	0.0367	0.0254	0.0156	0.0084	0.0015	-0.0037	-0.0083	-0.0114	-0.0144	-0.0165
0.4	0.1307	0.1297	0.1247	0.1119	0.0883	0.0692	0.0523	0.0424	0.0275	0.0173	0.0093	0.0028	-0.0022	-0.0070	-0.0105	-0.0132	-0.0152
0.5	0.1108	0.1012	0.1007	0.0975	0.0824	0.0659	0.0512	0.0386	0.0275	0.0184	0.0105	0.0041	-0.0013	-0.0060	-0.0094	-0.0123	-0.0145
0.6	0.0949	0.0877	0.0858	0.0850	0.0722	0.0606	0.0482	0.0379	0.0274	0.0189	0.0111	0.0055	-0.0003	-0.0045	-0.0081	-0.0110	-0.0134
0.7	0.0811	0.0821	0.0818	0.0765	0.0666	0.0578	0.0462	0.0366	0.0272	0.0192	0.0121	0.0061	+0.0010	-0.0032	-0.0069	-0.0098	-0.0121
0.8	0.0715	0.0710	0.0760	0.0660	0.0601	0.0516	0.0434	0.0344	0.0264	0.0195	0.0124	0.0069	0.0019	-0.0027	-0.0050	-0.0087	-0.0110
0.9	0.0620	0.0619	0.0610	0.0579	0.0530	0.0469	0.0399	0.0323	0.0250	0.0186	0.0127	0.0075	0.0026	-0.0014	-0.0045	-0.0076	-0.0099
1.0	0.0513	0.0542	0.0540	0.0504	0.0472	0.0425	0.0366	0.0300	0.0235	0.0175	0.0126	0.0076	0.0032	-0.0006	-0.0038	-0.0056	-0.0080
1.1	0.0476	0.5176	0.0174	0.0456	0.0408	0.0372	0.0330	0.0272	0.0220	0.0167	0.0121	0.0077	0.0036	0	-0.0030	-0.0047	-0.0072
1.2	0.0412	0.0412	0.0389	0.0390	0.0372	0.0332	0.0288	0.0245	0.0205	0.0156	0.0112	0.0074	0.0036	+0.0006	-0.0023	-0.0044	-0.0063
1.3	0.0360	0.0360	0.0360	0.0310	0.0325	0.0290	0.0259	0.0221	0.0190	0.0160	0.0106	0.0069	0.0030	0.0010	-0.0018	-0.0037	-0.0053
1.4	0.0311	0.0313	0.0311	0.0303	0.0283	0.0260	0.0228	0.0199	0.0165	0.0131	0.0099	0.0067	0.0030	0.0010	-0.0016	-0.0037	-0.0053
1.5	0.0273	0.0272	0.0272	0.0264	0.0247	0.0225	0.0203	0.0175	0.0146	0.0119	0.0092	0.0062	0.0032	0.0010	-0.0003	-0.0021	-0.0037
1.6	0.0240	0.0239	0.0239	0.0230	0.0221	0.0201	0.0181	0.0159	0.0133	0.0107	0.0082	0.0057	0.0032	0.0010	-0.0003	-0.0021	-0.0037
1.7	0.0203	0.0208	0.0208	0.0198	0.0192	0.0177	0.0162	0.0137	0.0118	0.0096	0.0072	0.0050	0.0030	0.0010	-0.0003	-0.0021	-0.0037
1.8	0.0180	0.0179	0.0178	0.0172	0.0166	0.0153	0.0130	0.0121	0.0104	0.0082	0.0067	0.0056	0.0024	0.0017	-0.0003	-0.0021	-0.0037
1.9	0.0156	0.0156	0.0156	0.0150	0.0143	0.0132	0.0110	0.0105	0.0085	0.0067	0.0052	0.0043	0.0039	0.0012	-0.0001	-0.0016	-0.0032
2.0	0.0135	0.0135	0.0134	0.0132	0.0130	0.0126	0.0121	0.0116	0.0098	0.0074	0.0059	0.0040	0.0030	0.0009	0	-0.0015	-0.0029
2.1	0.0116	0.0116	0.0116	0.0114	0.0112	0.0108	0.0104	0.0101	0.0081	0.0074	0.0059	0.0040	0.0030	0.0009	0	-0.0011	-0.0025
2.2	0.0096	0.0096	0.0096	0.0095	0.0095	0.0092	0.0088	0.0084	0.0069	0.0063	0.0054	0.0032	0.0024	0.0005	0	-0.0004	-0.0015
2.3	0.0072	0.0072	0.0072	0.0070	0.0069	0.0062	0.0060	0.0059	0.0041	0.0037	0.0031	0.0017	0.0011	0	-0.0007	-0.0015	-0.0024
2.4	0.0051	0.0051	0.0051	0.0050	0.0049	0.0047	0.0044	0.0042	0.0038	0.0024	0.0020	0.0007	0.0003	0	-0.0009	-0.0015	-0.0020
2.5	0.0034	0.0034	0.0034	0.0033	0.0032	0.0030	0.0028	0.0026	0.0020	0.0014	0.0011	0.0005	0	-0.0004	-0.0008	-0.0013	-0.0018
2.6	0.0022	0.0022	0.0022	0.0022	0.0021	0.0020	0.0019	0.0017	0.0015	0.0008	0.0006	0	0	-0.0006	-0.0009	-0.0013	-0.0015
2.7	0.0014	0.0014	0.0014	0.0013	0.0013	0.0012	0.0011	0.0010	0.0008	0.0005	0.0003	0	-0.0005	-0.0006	-0.0009	-0.0012	-0.0014
2.8	0.0008	0.0008	0.0008	0.0007	0.0007	0.0006	0.0005	0.0004	0.0003	0.0002	0	0	-0.0005	-0.0006	-0.0009	-0.0011	-0.0012
2.9	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	-0.0005	-0.0006	-0.0007	-0.0009	-0.0011	-0.0011
3.0	0	0	0	0	0	0	0	0	0	0	0	-0.0005	-0.0006	-0.0007	-0.0009	-0.0011	-0.0011
3.1	0	0	0	0	0	0	0	0	0	0	0	-0.0005	-0.0006	-0.0007	-0.0009	-0.0011	-0.0011
3.2	0	0	0	0	0	0	0	0	0	0	0	-0.0005	-0.0006	-0.0007	-0.0009	-0.0011	-0.0011
3.3	0	0	0	0	0	0	0	0	0	0	0	-0.0005	-0.0006	-0.0007	-0.0009	-0.0011	-0.0011
3.4	0	0	0	0	0	0	0	0	0	0	0	-0.0005	-0.0006	-0.0007	-0.0009	-0.0011	-0.0011
3.5	0	0	0	0	0	0	0	0	0	0	0	-0.0005	-0.0006	-0.0007	-0.0009	-0.0011	-0.0011
3.6	0	0	0	0	0	0	0	0	0	0	0	-0.0005	-0.0006	-0.0007	-0.0009	-0.0011	-0.0011
3.7	0	0	0	0	0	0	0	0	0	0	0	-0.0005	-0.0006	-0.0007	-0.0009	-0.0011	-0.0011
3.8	0	0	0	0	0	0	0	0	0	0	0	-0.0005	-0.0006	-0.0007	-0.0009	-0.0011	-0.0011
3.9	0	0	0	0	0	0	0	0	0	0	0	-0.0005	-0.0006	-0.0007	-0.0009	-0.0011	-0.0011
4.0	0	0	0	0	0	0	0	0	0	0	0	-0.0005	-0.0006	-0.0007	-0.0009	-0.0011	-0.0011

Table 40 (Cont'd.)

$\eta(\xi)$	1,6	1,7	1,8	1,9	2,0	2,1	2,2	2,3	2,4	2,5	2,6	2,7	3,0	3,2	3,4	3,6	3,8	4,0
0	-0,0191	-0,0201	-0,0216	-0,0210	-0,0212	-0,0208	-0,0207	-0,0195	-0,0181	-0,0170	-0,0146	-0,0129	-0,0111	-0,0094	-0,0076	-0,0059	-0,0045	-0,0035
0,05	-0,0191	-0,0201	-0,0207	-0,0210	-0,0212	-0,0208	-0,0207	-0,0195	-0,0181	-0,0170	-0,0146	-0,0129	-0,0111	-0,0094	-0,0076	-0,0059	-0,0045	-0,0035
0,1	-0,0190	-0,0200	-0,0206	-0,0210	-0,0212	-0,0208	-0,0207	-0,0195	-0,0181	-0,0170	-0,0146	-0,0129	-0,0111	-0,0094	-0,0076	-0,0059	-0,0045	-0,0035
0,2	-0,0189	-0,0199	-0,0203	-0,0207	-0,0210	-0,0208	-0,0206	-0,0195	-0,0180	-0,0170	-0,0146	-0,0129	-0,0111	-0,0094	-0,0076	-0,0059	-0,0045	-0,0035
0,3	-0,0181	-0,0191	-0,0199	-0,0201	-0,0209	-0,0206	-0,0205	-0,0194	-0,0180	-0,0171	-0,0146	-0,0129	-0,0111	-0,0094	-0,0076	-0,0059	-0,0045	-0,0035
0,4	-0,0170	-0,0184	-0,0192	-0,0197	-0,0206	-0,0204	-0,0204	-0,0194	-0,0180	-0,0171	-0,0146	-0,0129	-0,0111	-0,0094	-0,0076	-0,0059	-0,0045	-0,0035
0,5	-0,0162	-0,0175	-0,0184	-0,0189	-0,0204	-0,0204	-0,0202	-0,0194	-0,0179	-0,0170	-0,0146	-0,0129	-0,0111	-0,0094	-0,0076	-0,0059	-0,0045	-0,0035
0,6	-0,0153	-0,0164	-0,0175	-0,0180	-0,0200	-0,0200	-0,0200	-0,0192	-0,0178	-0,0170	-0,0146	-0,0129	-0,0111	-0,0094	-0,0076	-0,0059	-0,0045	-0,0035
0,7	-0,0141	-0,0155	-0,0165	-0,0174	-0,0175	-0,0178	-0,0176	-0,0176	-0,0168	-0,0156	-0,0136	-0,0120	-0,0102	-0,0080	-0,0070	-0,0054	-0,0044	-0,0034
0,8	-0,0128	-0,0143	-0,0154	-0,0169	-0,0171	-0,0176	-0,0174	-0,0167	-0,0160	-0,0146	-0,0128	-0,0112	-0,0097	-0,0081	-0,0070	-0,0054	-0,0044	-0,0034
0,9	-0,0119	-0,0130	-0,0141	-0,0149	-0,0167	-0,0172	-0,0171	-0,0165	-0,0159	-0,0145	-0,0128	-0,0112	-0,0097	-0,0081	-0,0070	-0,0054	-0,0044	-0,0034
1,0	-0,0107	-0,0122	-0,0138	-0,0145	-0,0151	-0,0158	-0,0153	-0,0147	-0,0144	-0,0135	-0,0122	-0,0110	-0,0090	-0,0079	-0,0067	-0,0059	-0,0048	-0,0038
1,1	-0,0097	-0,0112	-0,0121	-0,0137	-0,0145	-0,0148	-0,0150	-0,0145	-0,0138	-0,0130	-0,0118	-0,0110	-0,0091	-0,0081	-0,0069	-0,0059	-0,0048	-0,0038
1,2	-0,0087	-0,0104	-0,0115	-0,0125	-0,0139	-0,0132	-0,0132	-0,0140	-0,0123	-0,0124	-0,0110	-0,0091	-0,0084	-0,0069	-0,0059	-0,0048	-0,0038	-0,0028
1,3	-0,0079	-0,0092	-0,0104	-0,0111	-0,0125	-0,0130	-0,0129	-0,0128	-0,0126	-0,0104	-0,0097	-0,0086	-0,0080	-0,0067	-0,0057	-0,0048	-0,0038	-0,0028
1,4	-0,0070	-0,0084	-0,0099	-0,0106	-0,0110	-0,0113	-0,0115	-0,0126	-0,0106	-0,0104	-0,0097	-0,0086	-0,0080	-0,0067	-0,0057	-0,0048	-0,0038	-0,0028
1,5	-0,0062	-0,0078	-0,0087	-0,0096	-0,0099	-0,0110	-0,0112	-0,0117	-0,0105	-0,0104	-0,0095	-0,0085	-0,0073	-0,0060	-0,0057	-0,0048	-0,0038	-0,0028
1,6	-0,0057	-0,0069	-0,0079	-0,0082	-0,0086	-0,0089	-0,0102	-0,0115	-0,0104	-0,0095	-0,0085	-0,0079	-0,0062	-0,0050	-0,0044	-0,0035	-0,0025	-0,0015
1,7	-0,0051	-0,0064	-0,0075	-0,0080	-0,0085	-0,0089	-0,0100	-0,0090	-0,0092	-0,0080	-0,0079	-0,0074	-0,0052	-0,0040	-0,0034	-0,0025	-0,0015	-0,0005
1,8	-0,0047	-0,0058	-0,0066	-0,0072	-0,0082	-0,0087	-0,0096	-0,0086	-0,0081	-0,0080	-0,0080	-0,0074	-0,0050	-0,0040	-0,0034	-0,0025	-0,0015	-0,0005
1,9	-0,0042	-0,0052	-0,0060	-0,0069	-0,0076	-0,0081	-0,0080	-0,0078	-0,0076	-0,0076	-0,0068	-0,0066	-0,0058	-0,0054	-0,0044	-0,0035	-0,0025	-0,0015
2,0	-0,0037	-0,0047	-0,0056	-0,0064	-0,0070	-0,0070	-0,0069	-0,0075	-0,0071	-0,0069	-0,0065	-0,0065	-0,0054	-0,0054	-0,0044	-0,0035	-0,0025	-0,0015
2,1	-0,0035	-0,0044	-0,0053	-0,0060	-0,0061	-0,0069	-0,0069	-0,0067	-0,0067	-0,0065	-0,0064	-0,0064	-0,0054	-0,0054	-0,0044	-0,0035	-0,0025	-0,0015
2,2	-0,0031	-0,0042	-0,0050	-0,0052	-0,0058	-0,0050	-0,0050	-0,0050	-0,0050	-0,0050	-0,0050	-0,0050	-0,0040	-0,0040	-0,0034	-0,0025	-0,0015	-0,0005
2,4	-0,0031	-0,0036	-0,0038	-0,0045	-0,0047	-0,0048	-0,0053	-0,0048	-0,0046	-0,0046	-0,0044	-0,0044	-0,0036	-0,0036	-0,0034	-0,0025	-0,0015	-0,0005
2,6	-0,0025	-0,0029	-0,0033	-0,0036	-0,0039	-0,0042	-0,0044	-0,0044	-0,0044	-0,0044	-0,0040	-0,0036	-0,0034	-0,0034	-0,0029	-0,0022	-0,0018	-0,0013
2,8	-0,0022	-0,0026	-0,0027	-0,0028	-0,0031	-0,0031	-0,0037	-0,0033	-0,0033	-0,0033	-0,0033	-0,0032	-0,0028	-0,0028	-0,0024	-0,0020	-0,0018	-0,0013
3,0	-0,0018	-0,0020	-0,0023	-0,0026	-0,0026	-0,0030	-0,0030	-0,0030	-0,0030	-0,0030	-0,0030	-0,0030	-0,0026	-0,0026	-0,0022	-0,0020	-0,0018	-0,0013
3,2	-0,0016	-0,0018	-0,0020	-0,0021	-0,0021	-0,0023	-0,0023	-0,0023	-0,0023	-0,0023	-0,0023	-0,0023	-0,0023	-0,0023	-0,0023	-0,0023	-0,0023	-0,0023
3,4	-0,0014	-0,0015	-0,0017	-0,0018	-0,0019	-0,0019	-0,0019	-0,0019	-0,0019	-0,0019	-0,0019	-0,0019	-0,0019	-0,0019	-0,0019	-0,0019	-0,0019	-0,0019
3,6	-0,0012	-0,0014	-0,0014	-0,0015	-0,0016	-0,0016	-0,0016	-0,0016	-0,0017	-0,0017	-0,0017	-0,0017	-0,0017	-0,0017	-0,0017	-0,0017	-0,0017	-0,0017
3,8	-0,0007	-0,0012	-0,0012	-0,0013	-0,0013	-0,0014	-0,0014	-0,0014	-0,0013	-0,0013	-0,0013	-0,0013	-0,0013	-0,0013	-0,0013	-0,0013	-0,0013	-0,0013
4,0	-0,0005	-0,0010	-0,0010	-0,0011	-0,0011	-0,0011	-0,0011	-0,0011	-0,0010	-0,0010	-0,0010	-0,0010	-0,0010	-0,0010	-0,0010	-0,0010	-0,0010	-0,0010

- Notes. 1. The values of  $\bar{M}_y^1$  are found with substitution in the table of the entry under  $\xi$  by the entry under  $\eta$  and vice versa, for this case the designation of columns is shown in brackets.
2. For intermediate values of  $\xi$  and  $\eta$  values  $\bar{M}_x^1$  and  $\bar{M}_y^1$  are taken by interpolation.

5) We determine the computed value of bending moment

$$M_p = KM_{x(y)}. \quad (43)$$

where K - the coefficient which considers the possible increase of bending moments with the position of load in the edge zones of slabs.

If in the seams between slabs we construct butt joints or with through joints we provide strengthening of the edge sections by slabs under the joints or by reinforcement, the value of coefficient K is taken as:

1.2 - for concrete and reinforced concrete coverings, and also cast in-situ prestressed coverings with biaxial compression when determining the calculated moment in longitudinal direction;

1.0 - for coverings of precast prestressed ferroconcrete slabs, cast in-situ prestressed coverings with uniaxial compression, and also with biaxial compression when determining the calculated moment in transverse direction.

#### Determination of Maximum Permissible Bending Moments

The maximum permissible bending moments are determined by formulas:

a) for concrete and reinforced concrete sections

$$M_{np} = mk_0 R_{pn} \frac{bh^3}{6} \text{ kgf} \cdot \text{cm}, \quad (44)$$

where m - the coefficient of operating conditions, which considers: the effect of repetition of loading both on the development of fatigue phenomena in the material of covering and on the possible accumulation of residual deformations in the base; the increase of the strength of concrete with time; temperature stresses; the degree of danger of the appearance of

cracks in the covering for its operation; values of  $m$  are given in Table 38;

$k_6$  - the degree of uniformity of concrete, which considers the possible deviation of the strength of concrete from the designed brand; its value is taken as 0.7;

$R_{PH}^H$  - standard tensile strength of concrete with bending, it is taken equal to the brand on bending,  $\text{kgf/cm}^2$ ;

b) for ordinary ferroconcrete sections

$$M_{np} = m F_a R_a z_1, \quad (45)$$

where  $F_a$  - the area of the section of reinforcement in the tension zone,  $\text{cm}^2$ ;

$R_a$  - the calculated strength of reinforcement,  $\text{kgf/cm}^2$ ;

$z_1$  - arm of internal pair,  $\text{cm}$ ;

c) for prestressed sections

$$M_{np} = m (R_{pn} k_6 m_6 + \sigma_{6T} - \sigma_{6A}) \frac{bh^3}{6} \text{ kgf} \cdot \text{cm}, \quad (46)$$

where  $m_6$  - coefficient of the operating conditions of concrete during calculation with respect to cracking. The value of this coefficient during the calculation of airfield coverings is taken as 1.2;

$\sigma_{6T}$  - the magnitude of losses of prestressing in concrete, caused by friction of the covering against the base (it is taken as 1  $\text{kgf/cm}^2$  for each 10 m of stretched section);

$\sigma_{6A}$  - the magnitude of established prestresses in the outermost fiber of concrete of the tension zone, which is determined according to SNiP II-V. 1-62.

Determination of the Width of the Crack  
Opening in Sections Reinforced by  
Unstretched Reinforcement

The width of the crack opening in sections reinforced by unstretched reinforcement is determined by formula

$$a_r = \frac{\sigma_r}{E_s} l, \text{ cm}, \quad (47)$$

where  $E_a$  - the elastic modulus of reinforcement,  $\text{kgf/cm}^2$ ;

$\sigma_a$  - stress in reinforcement,  $\text{kgf/cm}^2$ ;

$$\sigma_a = \frac{M_p}{m F_a z_1} \frac{\text{kgf}}{\text{cm}^2} \quad (48)$$

$l_r$  - distance between cracks

$$l_r = k_1' \frac{F_a E_a}{S_a E_s} \eta_1 \text{ cm}, \quad (49)$$

$k_1'$  - coefficient which is determined by formula

$$k_1' = \frac{6h^2 E_s}{3.5 F_a z_1 E_a} - 2; \quad (50)$$

$\eta_1$  - coefficient depending on the type of reinforcement. It is equal to: 0.7 - for indented reinforcement; 1.0 - for smooth rods; 1.25 - for welded mesh from cold-drawn wire.

#### Features of Calculation of Rigid Single-Layer Coverings, Constructed on Durable Artificial Bases

The construction of durable artificial bases - an effective means of increase of the bearing capacity and service life of rigid airfield coverings. However from a calculation point of view this question until now was still insufficiently studied. Approximate methods of calculation are used, which do not entirely consider the positive role of the construction of durable bases for rigid coverings.

The most theoretically and experimentally substantiated procedure is the one whose basis is formed by the general theory of calculation of nonrigid coverings used in the USSR, according to which a multilayer system of materials with different moduli of deformation is reduced to a single-layer system with modulus of deformation equivalent to it. In this case in the procedure there is considered the main feature of operation of artificial bases under rigid coverings, involving the fact that the relative

deflections, which they obtain during the action of a wheel load on the covering, is considerably less than in nonrigid coverings.

This feature affects both the character of stress distribution in the base and the calculated value of its deformation modulus. With small relative deformations the stress distribution in the bases of coverings will approach the relationships valid for elastic bodies.

In the empirical formula of Soyuzdronii, which expresses the stress distribution in the base along the vertical axis under the punch

$$\sigma = \frac{p}{1 + a \left( \frac{z_{\text{экс}}}{d} \right)^2} \text{ kgf/cm}^2 \quad (51)$$

where  $p$  - calculated load on punch,  $\text{kgf/cm}^2$ ;

$z_{\text{экс}}$  - the equivalent depth of placement of the calculated section, cm;

coefficient  $a$ , depending on the stress concentration under the punch, is taken as 1 during the calculation of nonrigid coverings; for isotropic-elastic bodies it is 2.5. During the calculation of bases under rigid coverings it is accepted as 2.0.

In this case the formula for determining the relative thickness of artificial base by the theory of calculation of nonrigid coverings takes the following form:

$$\frac{h}{d} = \frac{1}{1.41\pi} \lg \frac{1.57 \left( 1 - \frac{E_0}{E_{\text{экс}}} \right)}{1 - \frac{1}{n^{3.5}}}. \quad (52)$$

where  $h$  - the required thickness of artificial base, cm;

$d$  - diameter of the circle of transmission of load to the base, cm;

$E_0$  - modulus of deformation of the underlying soil;

$E_{\text{экв}}$  - equivalent modulus of deformation of the system  
"soil + artificial base";

$$n = \sqrt[3]{\frac{E_{\text{осб}}}{E_s}} \quad (53)$$

where  $E_{\text{осб}}$  - modulus of deformation of the artificial base,  
kgf/cm<sup>2</sup>.

The modulus of deformation of both soil and artificial bases is found depending on the relative deformation. The relative deformations of bases of rigid coverings do not exceed, as a rule,  $1 \times 10^{-4}$ . The values of the moduli of deformation of the materials used in artificial bases of rigid coverings are taken for these values of relative deformations.

With the construction of a durable artificial base the area of transmission of pressure to the soil is increased, in consequence of which the modulus of its deformation increases. This is considered quantitatively in the calculation procedure by the introduction of correction factor  $k_{\text{rp}}$  when determining the modulus of deformation of the soil.

Calculation is by the method of successive approximations in the following sequence.

1) We preliminarily designate the construction of strictly the coverings so that the bending moment from the load with construction of the covering without a durable base would exceed limiting moment  $M_{\text{np}}$  by 10-15%. By the trial-and-error method we select the required value of the substratum coefficient of the soil base  $C_{\text{rp}}$  for the case of construction of covering without durable base.

2) We calculate the required equivalent modulus of deformation of the base

$$E_{\text{np}} = 1.8 \sqrt[4]{BC_{\text{np}}} \text{ kgf/cm}^2 \quad (54)$$

3) We determine the conditional diameter of the circle of transmission of load from the covering to the base

$$d_{\text{v}} = \frac{2.50}{\sqrt{K_{\text{w}}}} l_{\text{np}} \text{ cm} \quad (55)$$

Here

$$l_{\text{np}} = \sqrt[4]{\frac{B}{C_{\text{np}}}} \quad (56)$$

where B - the rigidity of slab;

$K_{\text{w}}$  - the coefficient, which for prestressed coverings with uniaxial compression is determined according to the chart provided on Fig. 44, and for other types of coverings is taken as 1.

4) We calculate the modulus of deformation of the underlying soil by formula

$$E_0 = 1.8 \sqrt[4]{BC^3} \text{ kgf/cm}^2 \quad (57)$$

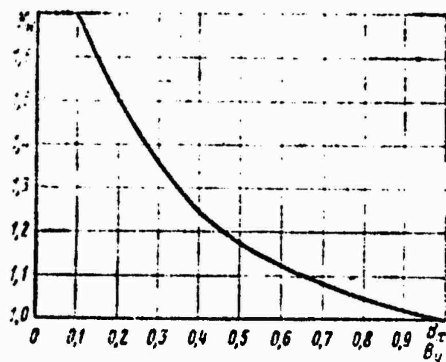


Fig. 44. Value of coefficient  $K_w$  depending on the rigidity ratio  $\frac{B_x}{B_y}$ .

5) We designate the material of the artificial base and by tables we determine the value of its modulus of deformation  $E_{\text{och}}$ .



6) By Fig. 45 we determine ratio  $\frac{d}{h}$ , for which we preliminarily establish the value of coefficient  $k_{rp}$ . Initial value of  $k_{rp}$  is taken as 2 and by calculated values of  $\frac{E_{1p}^{exp}}{k_{rp} E_0}$  and  $\frac{E_{ocb}}{k_{rp} E_0}$  (58) we establish its value on the chart of Fig. 45.

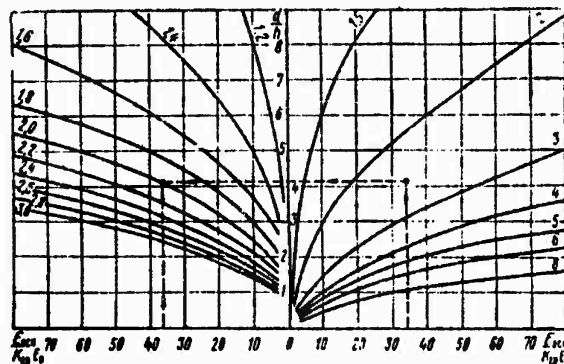


Fig. 45. Chart for determining  $\frac{d}{h}$  (numerals on the right curves indicate the value of  $\frac{E_{1p}^{exp}}{k_{rp} E_0}$ , on the left -  $k_{rp}$ ).

If the value of  $k_{rp}$  taken and obtained on the chart differs by more than 10%, we take a new value of  $k_{rp}$  and by the method of successive approximations we attain agreement of the values accepted and obtained by the chart.

7) We determine the required thickness of the artificial base

$$h_{1p} = \frac{d_v}{h} \text{ cm.}$$

## CHAPTER VIII

### NONRIGID TYPE COVERINGS

#### § 34. CHARACTERISTIC OF COVERINGS AND VARIETY OF THEIR CONSTRUCTIONS

Nonrigid type coverings should possess sufficient bearing capacity and provide safe operation of aircraft. The thickness and construction of nonrigid coverings depend on the magnitude of calculated loads of the aircraft and diagram of support points, the intensity of operation of the airfield and the quality of natural soil bases. Nonrigid type coverings are set up in the form of a multilayer construction of stone materials and local soils, treated, as a rule, with binding materials.

The construction of the nonrigid covering consists of top layer, supporting layer and artificial base (Fig. 46).



Fig. 46. Diagram of nonrigid type covering: 1 - top layer; 2 - supporting layer; 3 - artificial base; 4 - natural soil base.

The top layer should correspond to the following requirements: should not allow the penetration of surface water into the supporting layer of covering; should shield the supporting layer from

collapse by repeated aircraft loads; withstand shear forces from the aircraft wheels, appearing during impacts, movement and braking; have an even surface, which does not allow the sliding of aircraft wheels and excessive wear of tires; should not be subjected to damage by the air jets of recip-engine aircraft and gas flow of jet engines.

Supporting layer - the basic structural element of the non-rigid covering. The main purpose of this layer consists of the transmission of pressure from the aircraft wheels to the natural soil base. In a number of cases the supporting layer performs the same functions as the top layer of the covering. The supporting layer should withstand the forces which appear in the layer itself from vertical loads of the aircraft; should not allow the destruction of the natural soil base; should withstand the change in volume and loss of supporting power with a change in the humidity.

The stability of the supporting layer is attained by the use of durable stoneware materials and fine fillers, selected in such a way that a uniform mixture is obtained, which during compaction would ensure a dense, well wedged mass. For improvement of the properties binding materials can be added to the supporting layer.

An artificial base in conjunction with the supporting layer transfers pressure from the aircraft wheels to the natural soil base. Artificial bases are constructed from durable stone materials and local soils, treated with binding agents; a layer of sand can also enter the composition of the artificial bases. In the II and III climate zones sand bases with thickness from 5 to 20 cm are constructed on soils which are highly over-moistened in the spring and autumn bad road period, with artificial bases from stone materials. They decrease the deformation of

coverings caused by swelling, and they prevent the mixing of crushed stone with the overmoistened underlying soil.

Under very favorable natural conditions of location of the airfield (southern travelling-climate zones) artificial bases cannot be made. In this case the coverings are constructed on the well compacted soil of the flying field. Depending on the materials and degree of stability there are used the types of non-rigid coverings indicated in Table 41.

Table 41

Type of covering	Name of covering
Fundamental	Asphalt, black crushed stone, being constructed by the impregnation method.
Improved	Black made of gravel and crushed stone mixtures, being constructed by the mixing method.
Simplified	Optimum soil mixtures (local soils, consolidated by binding agent).

The type of covering is selected on the basis of prescribed calculated loads (class of airfield), the presence of local building materials and the technical and economical comparisons of variants.

#### § 35. ASPHALT COVERINGS

Asphalt coverings - one of the basic types of nonrigid coverings and used on airfields with category of standard loads III, IV, V, VI. They have an even surface, allow the construction of economical structures with different thickness on different sections, create complete mechanization of operations and ensure rapid periods of building.

We construct asphalt coverings from a well compacted mixture of crushed stone, sand and mineral powder, connected together by bitumen. The coverings are set up on durable artificial bases (crushed stone, gravel, cement-concrete).<sup>1</sup>

At places of systematic starting and testing of engines it is recommended to reinforce the asphalt coverings with welded mesh made of wire 2.5-3.5 mm in diameter with mesh size 100 × 100 mm. The joining of mesh - overlapping, length of overlap in both directions - 100 mm.

On the end sections of RW there is reinforced a strip 15 m wide along the takeoff line. On group MS the reinforcement of asphalt concrete should be provided on the entire length of MS with width of the reinforced strip equal to 15 m.

At places of servicing and repair of aircraft for the preservation of coverings from the destructive action of spilled fuels and oils it is recommended to provide the laying of cement mortar of composition 1:1 on an unpacked asphalt mixture with subsequent compaction of the mixture with rollers; consumption of mortar is 4 l/m<sup>2</sup> of covering. The mortar is prepared from quick-setting cement of brand 350 with water-cement ratio 0.8, fine sand is used as filler. Additionally it is necessary to introduce plasticizing and water-drawing additions into the mortar.

The asphalt covering can be single-layer and two-layered (Fig. 47). On sections where large braking forces are developed during the aircraft motion, which causes large tangential stresses, asphalt concrete should be laid in two layers. Such sections

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<sup>1</sup>Asphalt coverings on cement-concrete bases can be considered as a variety of rigid coverings.

include the end sections of RW and main RD. On the remaining sections the covering can be constructed in one layer.

Single-layer asphalt coverings are constructed with thickness 4-6 cm, two-layered - 10-12 cm. The operating experience of asphalt coverings showed that with intense aircraft traffic and actual thickness of layers less than stipulated, there appeared cracks, potholes and other defects.

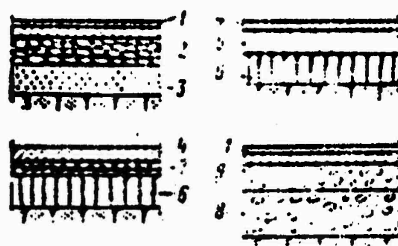


Fig. 47. Constructions of asphalt coverings: 1 - two-layered asphalt concrete; 2 - crushed stone; 3 - sand; 4 - single-layer asphalt concrete; 5 - cement-concrete; 6 - soil treated with cement or bitumen; 7 - black crushed rock; 8 - soil and gravel mixture; 9 - black gravel or soil and gravel mixture, treated with bitumen.

For the best adhesion of asphalt concrete with the stone base in the undercoat are packed coarse-grained mixtures with a smaller quantity of mineral powder and sand. In top layers we use fine-grained mixtures which provide increased strength and evenness of the covering. With the thickness of two-layered asphalt covering 10-12 cm (with the thickness of bottom layer 5-6 cm) the tangential stresses are decreased and reach a permissible magnitude.

Depending on the fineness of the mineral materials and the ratio of medium and fine fractions the asphalt concrete is subdivided into coarse-grained, medium-grained, fine-grained and sand. The coarse-grained mixtures are characterized by

maximum size of particles 40 mm; they are used in single-layer asphalt coverings and in the bottom layers of two-layered coverings. For coarse-grained asphalt concrete there are necessary uniform durable rocks, which are not broken up during packing. Medium-grained mixtures have size of the largest particles 20 mm. The crushed stone for such mixtures is prepared from less uniform stone materials (cobblestone and others). Medium-grained mixtures require a larger quantity of mineral powder and bitumen in comparison with coarse-grained mixtures. Fine-grained mixtures are characterized by maximum size of particles up to 15 mm; they are used in the top layers of asphalt coverings.

Sand mixtures (size of the largest particles up to 5 mm) require a still larger quantity of mineral powder and bitumen, therefore they are very sensitive to high temperatures. In order to avoid the appearance of waves and shears (in areas with hot climate), it is necessary to pay special attention to the thoroughness of selection and preparation of such mixtures.

Asphalt mixtures should conform to requirements GOST 9128-67 (Table 42). The mixture composition is selected on the basis of technical and economical substantiation taking into account the presence of local materials. In this case to provide the proper compaction the size of coarse particles of crushed stone, entering the asphalt mixtures, in the top layer should not exceed 0.6 the thickness of this layer and the bottom - 0.7. If the asphalt covering is constructed into one layer, then the maximum size of crushed stone should not exceed  $\frac{2}{3}$  of its thickness.

As mineral powders we use finely ground limestone, dolomite, marble, coal ash and natural finely pulverized soils, which possess low swelling.

Table 42.

Purpose and type of mixture	Size of sieve, mm											Approximate consumption of bitumen, % by weight	
	Content of grains of mineral material of this size, %												
	40	25	20	15	10	5	3	1.25	0.63	0.315	0.15		0.075
Mixtures of Continuous granulometry													
Top layer of covering													
Medium-grained													
A . . . . .	-	-	95-100	78-85	60-70	35-50	26-40	17-28	12-20	9-15	6-10	4-8	5-6.5
B . . . . .	-	-	95-100	85-91	70-80	50-65	40-55	28-39	25-29	14-22	9-15	6-10	5-6.5
C . . . . .	-	-	95-100	91-96	80-90	65-80	55-70	39-53	29-40	20-28	12-19	8-12	6.5-7.0
Fine-grained													
A . . . . .	-	-	-	95-100	63-75	35-50	26-40	17-28	12-20	9-15	6-10	4-8	5-6.5
A . . . . .	-	-	-	-	95-100	35-50	26-40	17-28	12-20	9-15	6-10	4-8	5-6.6
B . . . . .	-	-	-	95-100	75-85	50-65	40-55	28-39	20-29	14-22	9-15	6-10	5.5-7.0
B . . . . .	-	-	-	-	95-100	50-65	40-55	28-39	20-29	14-22	9-15	6-10	5.5-7.0
C . . . . .	-	-	-	95-100	85-93	65-80	57-70	39-53	29-40	20-28	12-19	8-12	6.0-7.5
C . . . . .	-	-	-	-	95-100	65-80	57-70	39-53	29-40	20-28	12-19	8-12	6.0-7.5
Sandy													
D . . . . .	-	-	-	-	-	95-100	75-88	45-67	28-50	18-35	11-23	8-14	7.5-9.0
E . . . . .	-	-	-	-	-	95-100	80-95	53-86	37-75	27-65	17-33	10-16	7.0-9.0



Table 42 (Cont'd.).

Purpose and type of mixture	Size of sieve, mm										Approximate consumption of bitumen, % by weight
	Content of grains of mineral material of this size, %										
	40	20	15	10	5	3	1.25	0.63	0.315	0.15	
Mixtures of intermittent granulometry											
Medium-grained											
A . . . . .	—	—	95-100	72-85	60-70	35-50	35-50	35-50	35-50	35-50	5-6.5
B . . . . .	—	—	95-100	85-91	70-80	50-65	50-65	50-65	50-65	50-65	5-6.5
Pine-grained:											
A . . . . .	—	—	—	95-100	63-75	35-50	35-50	35-50	35-50	35-50	5-6.5
A . . . . .	—	—	—	—	95-100	35-50	35-50	35-50	35-50	35-50	5-6.5
B . . . . .	—	—	—	95-100	75-80	50-65	50-65	50-65	50-65	50-65	5.5-7.0
B . . . . .	—	—	—	—	95-100	50-65	50-65	50-65	50-65	50-65	5.5-7.0
Bottom layer of covering (coarse- grained and medium-grained mixtures).	95-100	75-100	—	55-83	43-69	27-49	19-40	10-26	7-18	4-11	2-7
											0-4
											4-6

Notes. 1. The mixtures of intermittent granulometry are used in the form of an exception in the absence of coarse and medium sand and with the impossibility of enrichment of fine sand with waste of stone crushing.

2. One should increase the crushed stone content in mixtures (in the limits recommended by the table) when there is natural sand, and decrease it - in the case of the use of crushed sand.

3. The types of mixtures characterize the quantity of crushed stone: A - finely crushed mixture (50-65%); B - medium crushed mixture (35-50%); C - coarsely crushed mixture (20-35%); D - sand mixtures (33%) of crushed sand; E - sand mixtures from natural sand.

When selecting the brand of bitumen it is necessary to consider the climate conditions in which the airfield is constructed. As binding agent in asphalt concrete we use petroleum road bitumens, which conform to the requirements GOST 11954-66 (viscous) and GOST 11955-66 (liquid). Depending on the climate conditions for hot asphalt mixtures we use the following brands of bitumen:

- in I travelling-climate zone BND-90/130;
- in II travelling-climate zone BND-90/130 and BND-60/90;
- in IV and V travelling-climate zone BND-60/90 and BND-40/60.

The operating experience of large modern jet and turbojet aircraft showed that asphalt coverings are in good state if and only if the preparation and laying of asphalt-concrete mixtures occur in strict conformity with technical rules and GOST.

The asphalt-concrete mixture, as a rule, is laid in hot state and packed with rollers. Asphalt-concrete mixtures can also be laid in cold state. In this case it is necessary to bear in mind that right after laying the cohesion of cold mixtures is low, which also restricts the use of cold mixtures during the construction of asphalt coverings.

The effectiveness of the application of asphalt coverings is ensured only with a good quality of operations, therefore they should be performed in dry and warm weather. Special attention must be paid to the correct preparation of the asphalt-concrete mixture, joining of the earlier laid layer with the one newly laid.

#### § 36. CRUSHED STONE COVERINGS, CONSTRUCTED BY THE IMPREGNATION METHOD

Crushed stone coverings (Fig. 48), constructed by the impregnation method, have high strength, water resistance; lack

of dustiness; ensure year-round operation of aircraft with standard load on the strut from 5 to 30 t in II-V travelling-climate zones.

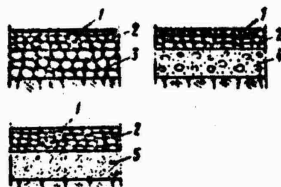


Fig. 48. The construction of black crushed stone coverings: 1 - surface treatment; 2 - black crushed stone; 3 - crushed stone; 4 - soil and gravel mixture, treated with bitumen.

Black crushed stone coverings are constructed by layers, according to the principle of garreting, of clean dry and uniform-strength crushed stone, selected by fractions. With each subsequent deposit of crushed stone there are simultaneously performed compaction and pouring of binding agent. Binding agent penetrates the thickness and together with the crushed stone creates a layer of stable and durable covering. Depending on the purpose of the covering the impregnation can be deep (6.5-8.0 cm) or light (4-6 cm). With deep impregnation there is used crushed stone of two-three fractions with maximum size of particles up to 65-70 mm, with light - crushed stone of two-three fractions with maximum size of particles up to 30-40 mm. For impregnation we use petroleum viscous bitumen BND-130/200, BND-90/130, viscous shale bitumen BS-1 and coal tar D-6 and D-7. The recommended dimensions of fractions, the consumption of stone materials and the standards of pouring of binding agent are given in Table 43.

Black crushed stone coverings are usually constructed on artificial bases from crushed stone, soil and crushed rock or soil and gravel mixture, and also from stabilized soils. Soil and crushed rock and soil and gravel bases can be treated with black binding agent by the method of mixing on the spot. During

Table 43

Impregnation	Quantity of procedures of depositing crushed stone	Order of depositing and pouring				Surface treatment	Overall consumption of materials
		I	II	III	IV		
Deep 6.5-8.0 cm (for coverings)	4	40-70	25-40	15-25	3(5)-15	3-5	10.2-13.4
Sizes of fractions, mm		4.5-6.0	3.0-4.0	1.0-1.1	0.9-1.1	0.8-1.2	9.0-11.5
Consumption: crushed stone, $\text{m}^3/100 \text{ m}^2$		3.0-4.0	2.5-3.0	2.0-2.5	1.5-2.0	—	—
Consumption: binding agent, $\text{l}/\text{m}^2$		—	—	—	—	—	—
Deep 6.5-8.0 cm	3	25-65	15-25	3(5)-15	—	3-5	10.2-13.4
Sizes of fractions, mm		7.5-10.0	1.0-1.1	0.9-1.1	—	0.8-1.2	8.5-11.5
Consumption: crushed stone, $\text{m}^3/100 \text{ m}^2$		5.0-7.0	2.0-2.5	1.5-2.0	—	—	—
Consumption: binding agent, $\text{l}/\text{m}^2$		—	—	—	—	—	—
Light 4-6 cm (for bases)	3	25-40	15-25	3(5)-15	—	—	5.9-8.6
Sizes of fractions, mm		3.0-4.5	2.0-3.0	0.9-1.1	—	—	5.0-6.5
Consumption: crushed stone, $\text{m}^3/100 \text{ m}^2$		3.0-4.0	2.0-2.5	—	—	—	—
Consumption: binding agent, $\text{l}/\text{m}^2$		—	—	—	—	—	—
Light 4-6 cm	2	25-40	3(5)-15	—	—	—	5.9-8.6
Sizes of fractions, mm		5.0-7.5	0.9-1.1	—	—	—	5.0-6.0
Consumption: crushed stone, $\text{m}^3/100 \text{ m}^2$		4.0-6.0	—	—	—	—	—
Consumption: binding agent, $\text{l}/\text{m}^2$		—	—	—	—	—	—

Note. The consumption norms of materials (crushed stone and binding agent) are given: smaller with impregnation to a depth of 6.0 and 4 cm, greater - 8.0 and 6.5 cm.

the construction of black crushed stone coverings we first crumble and slightly pack the one-dimensional layer of crushed stone; further we pour the bitumen, which seeps into the pores between the crushed stones. With further compaction by heavy rollers there is attained final distribution of bitumen in the crushed stone layer. The subsequent layers (second, third, fourth) are treated in the same order.

For preliminary compaction we use light rollers weighing 5-6 t, while for subsequent - heavy weighing 8-10 t. The rollers travel at a speed of 1.5-2.5 km/h. Light rollers pass from 2 to 5 times along one track. Compaction by heavy rollers is performed until the crushed stone takes a stable position; usually the number of passes of a heavy roller along one track is 4-5.

The final stage of work is the surface treatment, during which on the covering is poured bitumen or tar, then stone fines are broken up and compacted in several passes. As a result there is created a mat 0.5-1.5 cm thick, which increases the watertightness of coverings, decreases the movement resistance of transport devices and preserves the covering from wear. The recommended brands of binding agent for surface treatment are given in Table 41.

Table 41.

Material utilized for surface treatment	Bitumen			Coal tar
	Petroleum Viscous	Petroleum Liquid	Liquid and viscous	
Siftings (0-5 mm)	-	SG-40/70 MG-40/70	S-4 BS-0	D-4
Stone fines and key (5-15 and 12-25 mm).	BND-200/300 BND-130/200	SG-70/130 SG-130/200 MG-130/200	S-5 S-6	D-5 D-6

§ 37. COVERINGS OF GRAVEL AND CRUSHED  
STONE MIXTURES, CONSTRUCTED BY THE  
MIXING METHOD

The coverings of gravel and crushed stone mixtures, constructed by the mixing method, are sufficiently waterproof, dense, elastic and allow year-round operation of the aircraft with standard load on the strut from 5 to 8 t in II-V travelling-climate zones. As mineral material we use the gravel and crushed stone material of the local quarries. Crushed stone of reduced strength is allowed. It is advantageous to construct coverings by the method of impregnation from crushed stone of solid rock. Gravel and crushed stone mixtures are selected according to the principle of the greatest density. In the mixture there is a certain part of loamy and dusty particles of ground stone rock, which connect skeleton particles together. Gravel and crushed stone mixtures are selected in certain ratios, which ensure mechanical strength and water resistance.

Black gravel and crushed stone coverings (Fig. 49) are single-layer and two-layered. Single-layer coverings are allowed only on airfields located in the V travelling-climate zone. For the bottom layer of two-layered coverings we use black gravel and crushed stone mixtures; the construction of bottom layers without treatment with binding agent is also allowed. The thickness of coverings depends upon the aircraft weight, mechanical characteristics of the underlying soil and on the average changes from 10 to 40 cm.



Fig. 49. The construction of a covering from gravel and crushed stone mixtures, constructed by the mixing method. 1 - surface treatment; 2 - layer treated with binding agent; 3 - layer not treated with binding agent.

With the calculated thickness of the covering more than 15 cm two-layered coverings are constructed. The minimum thickness of the top layer of two-layered covering is 5 cm. The longitudinal edges of the covering of RD are thickened by 5-8 cm for their strengthening and insulation of the base.

To provide watertightness and stability of the top layer of the covering it is mandatory to construct a protective layer by the method of surface impregnation.

Coverings are laid on the natural soil base, pre-compacted to density not less than 95% of the maximum, determined in the laboratory by the method of standard compaction. For raising the strength and service life of the sections which undergo the intense action of aircraft loads (starting sections, places where taxiways adjoin the runway; sections of liftoff of aircraft during takeoff), the coverings are constructed by the impregnation method or by means of addition of cement or unslaked lime into the mixture. The quantity of additions of cement or lime for gravel and crushed stone mixtures is 2-3% of the weight of the mineral part.

The approximate compositions of the optimum gravel and crushed stone mixtures for the construction of black coatings are given in Table 45. For the coverings constructed by the method of mixing on the spot liquid bitumen can be used (Table 46).

The brand of bitumen is established depending on the building area of the airfield. In a hot climate we use bitumen of increased viscosity, in the areas with greater amount of precipitation - liquid or shale bitumen, which provide shorter periods of forming and high solidity of coverings. The consumption of liquid bitumen is 4-7% of the weight of mineral material.

Table 45

Mixture	Size of sieve openings, mm											
	50	40	25	15	5	2	1	0.5	0.25	0.15	0.07	0.005
Quantity of particles passing through the sieve, % by weight												
Top and bottom layer												
Coarse-grained	-	100	85	70	43	28	22	15	10	8	7	7
Medium-grained	-	-	95	85	65	52	43	35	28	25	20	18
Fine-grained	-	-	100	80	50	33	25	18	13	10	8	8
Soil	-	-	-	95	85	70	55	40	35	28	23	21
	-	-	-	100	63	40	30	22	15	12	10	10
	-	-	-	-	90	75	60	45	36	30	25	22
	-	-	-	-	-	100	70	48	32	24	16	13
	-	-	-	-	-	-	85	70	60	50	40	36
Only for bottom layer												
Coarse-grained	100	-	75	60	35	25	-	-	10	-	5	4
100	-	-	55	30	-	-	-	-	-	-	-	-
-	100	-	80	57	30	15	10	5	3	1	-	-
-	-	-	85	80	60	50	-	-	30	-	18	17
-	-	-	85	70	43	28	22	15	10	8	7	7
-	-	-	75	60	35	25	-	-	10	-	5	4
-	-	-	100	70	35	18	12	6	4	2	-	8
Medium-grained	-	-	-	80	50	33	25	18	13	10	8	-
Fine-grained	-	-	-	100	50	25	15	10	5	2	-	-
	-	-	-	-	63	40	30	22	15	12	10	10

Note. The content of particles smaller than 0.005 mm (clays) in soil and gravel and soil and crushed stone mixtures for the top layer should be not more than 3%, and for bottom - 5%.



Table 46

Method of creation of mixture	Bitumen			Coal tar
	Petroleum viscous	Petroleum liquid	Shale Liquid and Viscous	
Mixing on the spot	-	SG-15/25 SG-25/40 MG-25/40 MG-40/70	S-3 S-4 S-5 -	D-3 D-4 - -
Mixing in installations:				
Without preheating of mineral materials	-	SG-25/40 SG-40/70 MG-25/40 MG-40/70	S-4 S-5 - -	D-4 D-5 - -
With preheating of mineral materials:				
Warm mixtures	BND-200/300	SG-130/200 MG-130/200	S-6 BS-0	D-6 -
	BND-130/200	-	BS-1	D-7
	BND-90/130		BS-11	D-8
	BND-60/90		BS-111	-
	BND-40/60			
Cold mixtures	-	SG-40/70 SG-70/130 MG-40/70 MG-70/130	S-6 - - -	D-6 - - -

A high quality of coverings is attained if the moisture of mineral materials is optimum. With insufficient moisture, as a result of low viscosity the coverings are easily destroyed; with excess moisture during the period of compaction waves and cracks are formed, therefore the moisture content by weight of mineral materials being recommended should be 3-5%.

The gravel and crushed stone mixtures, treated with liquid bitumen, with respect to strength and water resistance should satisfy the following requirements:

Compressive strength at 50°C not less than	5 kgf/cm <sup>2</sup>
Compressive strength at 20°C not less than	8 kgf/cm <sup>2</sup>
Compressive strength at 20°C in water-saturated state not less than	5 kgf/cm <sup>2</sup>
Water saturation according to weight not more than	3%
Swelling according to volume not more than	3%

The mixture for the construction of coverings from gravel and crushed stone mixtures can be prepared by the method of mixing on the spot, in a stationary or mobile mixing installation. Mixing on the spot is the most economic and effective; it can be accomplished by disk harrows, cultivators, motorized road graders and road harrows.

Black coverings should be constructed in the warm season and finished so that the forming of the covering during 20-30 days would occur at air temperature not below +10°C and before the onset of the rainy period. In this case uniform distribution of bitumen, uniformity and strength of black coatings are attained.

#### § 38. SIMPLIFIED COVERINGS

Simplified coverings are constructed by means of consolidation of the local soils. Consolidation imparts to the soils water resistance, density, lack of dustiness and ensures the operation of aircraft with standard load on the strut from 5 to 8 t on airfields located in IV and V climate zones.

In the practice of airfield building the most common are: consolidation by the additions of other soil, gravel, crushed stone, changing the granulometric composition of the local soil before the formation of optimum mixtures; consolidation by binding bitumen, tar, cement, lime, increasing the cohesion and the water resistance of the local soils.

We resort to consolidation by the additions of other soil when the granulometric composition of the local soils is characterized by deficiency or by excess of basic fractions - sand, dust and clay. With a deficiency of dust and clay the cohesion of soils in dry state is decreased, but if they are in excess, then with moistening in the soil plastic deformations intensely develop. In both cases the resistance of soil to external loads is decreased and the operating conditions of the flying field become inadmissible.

The soil mixtures of optimum granulometric composition under variable conditions of moistening possess constant resistance to aircraft loads. For the creation of optimum mixtures to heavy loamy, dusty and clay local soils we add sand and gravel materials; to dusty and sandy local soils - loamy soils. We add sand and gravel particles also to the local soils in the areas of over-moistening for imparting stability to the soil skeleton. For the calculation of optimum compositions of soil mixtures one should use the data of Table 47.

Table 47

No. of mixture	Size of seive openings, mm						
	40	20	10	5	2.5	0.63	<0.05
	Quantity of particles having passed through the sieve, % by weight						
1	100	60-80	45-65	30-55	20-45	15-35	7-20
2	-	80-95	65-90	50-75	35-65	20-45	8-25
3	-	-	90-100	70-85	45-75	25-55	8-25

For the creation of an airfield covering the soil optimum mixtures are treated with liquid bitumen by the method of mixing on the spot. When optimum soil mixtures are not treated, the surface of the coverings can be sowed with grass mixtures.

The reinforcement of local soils by bitumen and tar makes it possible to create sufficiently durable and water-resistant material. For the construction of coverings we use two methods - cold and hot. With the cold method we heat only the binding agents to 80-90°C; with hot - we heat the binding agent and soil to 120-150°C and mix in asphalt mixtures.

On airfields we construct the types of simplified coverings from the local soils, given in Table 48, consolidated by bitumen or tar.

Table 48

Method of treatment	Type of covering
Flushing of the surface of the packed soil with liquid bitumen or tar (oiling)	Soil covering freed of dust
Mixing of loosened soil on the soil flying strip with liquid bitumen or tar with the aid of harrows, graders and others; levelling and compaction	Temporary type coverings from soil, treated by mixing on the spot
Mixing of soil in an installation with liquid bitumen or tar without the preheating of soil, packing, levelling, compaction	Temporary type covering or base under the fundamental coverings of soil, treated in an installation
Mixing of dried up soil in an installation with bitumen or tar of increased viscosity, packing, levelling and compaction	

Soils with number of plasticity from 3 to 17 can be used, the soils with number of plasticity over 12 require an increased quantity of bitumen. Sand and sandy-loam soils with plasticity number less than 3 can be applied only for construction of the bottom layer of covering. Saline soils are not recommended. The norms of consumption of liquid bitumen for the reinforcement of soils are given in Table 49.

Table 49

Soil	Moisture, % of the weight of soil	Consumption of liquid bitumen (dehydrated)	
		% of the weight	kgf/m <sup>2</sup> of mixture in a dense body
Mixtures with number of plasticity 3-7	4-7	5-8	100-155
Loams with number of plasticity:			
7-12	6-10	8-12	155-200
12-17	8-10	12-10	200-250

For increasing the strength and stability of coverings on the separate intensely operating sections of the airfield there is recommended the addition of cement or unslaked lime in the amount of 3-4% of the weight of the mineral part (for loams with number of plasticity 7-12).

During the treatment of soil with cement there is formed a durable soil-cement framework, which forms a sufficiently durable and waterproof covering. The soil, treated with cement, has considerably greater strength than the same soil, but treated with bitumen; the modulus of deformation of soil-cement can be up to 1600 kgf/cm<sup>2</sup>, while the modulus of deformation of the soil treated with bitumen, not more than 800 kgf/cm<sup>2</sup>.

Cement-soil coverings can be constructed under more adverse weather conditions than black soil coverings. Cement-soil coverings require less expenditures for construction as compared with black soil coverings. The shortcomings of cement soil must include low resistance to abrasion. Therefore above the cement soil it is compulsory to construct surface treatment or a wear layer from materials treated with organic binding agent.

Cement-soil coverings are advisable on airfields located in III, IV and V travelling-climate zones. Cement soil is also used in bases under asphalt and black crushed stone coverings.

For treatment with cement the most suitable are soils of optimum composition, and also light loams and sandy loams close to them. Clay and loamy soils are broken up and mixed with cement with difficulty, they require more cement. The sandy soils, treated with cement, as a result of increased porosity have reduced strength.

It is not recommended to reinforce soils, which have humus substances which lower the water resistance and strength of the covering, with cement. For reinforcement by cement peat and swampy soils, or soils which contain more than 10% by weight humus substances and more than 4% water-soluble salts, and also acids, are not suitable. Cement soil coverings (Fig. 50) are constructed single-layer and two-layered. The layer of cement soil in single-layer coverings is established by calculation and should be not less than 8 cm and not more than 20 cm; the thickness of two-layered coverings is 25-35 cm.

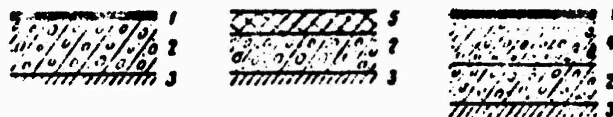


Fig. 50. Construction of cement soil covering: 1 - surface treatment; 2 - cement soil; 3 - packed soil; 4 - cement soil with increased cement content; 5 - asphalt concrete.

For the construction of cement-soil coverings there is used portland cement of grade not below 400; for bases the grade of cement can be lowered to 300. The tentative consumption of cement for 1 m<sup>3</sup> of cement soil is given in Table 50.

Table 50

Soil	Consumption of cement, kg/1 m <sup>3</sup>	
	For construction of covering	For construction of base
Optimum compositions, which do not contain humus	175-200	125-175
Heavy sandy loams, light loams and fine sand (content of humus <1%)	200-225	150-175
Silty and heavy loam (content of humus <1%)	225-250	175-225
Chernozems	225-250	200-250

Cement soil coverings with respect to strength and water resistance should satisfy the following requirements: compressive strength of water-saturated cylindrical samples 28 days in age ( $D = 5$  cm;  $H = 5.1$  cm) for coverings - not less than 30 kgf/cm<sup>2</sup>, for bases - not less than 20 kgf/cm<sup>2</sup>, ratio of compressive strength of water-saturated samples to the compressive strength of air-dried samples should be not less than 0.4-0.6; the modulus of deformation of water-saturated samples - not less than 1500-1000 kgf/cm<sup>2</sup>. With the construction of cement-soil coverings it is necessary to preliminarily break up the soil so that particles coarser than 5 mm would be no more than 25%, and coarser than 10 mm - not more than 10%. Further we evenly distribute the cement, mix it with soil, pour water, mix and pack the moistened mixture. After the termination of compaction we pour liquid bitumen at a rate of 0.8-1.2 l/m<sup>2</sup> and sprinkle sand with a layer of 1 cm. Surface treatment is constructed during the

consolidation of noncohesive soils in 7-10 days. For the construction of cement-soil coverings we use D-391 soil-mixing machines, D-530 road harrows, D-343A and D-343B cement spreaders.

Along with cement for the construction of coverings lime can be used in the form of lactic quicklime or slaked lime. The strength of the soil treated with lime is less than the strength of cement soil. With reinforcement by lime on the soils there are imposed the same requirements as during treatment with cement. Lime harmfully effects the mucous membranes of respiratory passages, therefore during the production of works it is necessary to especially observe the safety regulations.

Simplified airfield coverings require high quality of production of works. Therefore constant control must be accomplished of the quality of soils and optimum mixtures, their quantitative ratio, uniformity of mixing, moisture. The quality control of materials is produced by building laboratories.

#### § 39. PRINCIPLES OF CALCULATION OF NONRIGID COVERINGS

The types and constructions of nonrigid airfield coverings are established on the basis of calculations taking into account the category of design load, the climate and hydrogeological conditions, the presence of materials and features of the accepted method of production of works.

When determining the calculated thickness of covering as the strength criterion there is taken the magnitude of the maximum permissible relative deformation, being established by the stage of failure depending on the construction of covering:

$$H = \frac{d}{n} \operatorname{tg} \frac{90^\circ}{\frac{a}{b} - \frac{1}{n^{3.5}} + 1} ; \quad (60)$$



$$d = 1.13 \sqrt{\frac{P}{p}}; \quad (61)$$

$$p = 1.05 g_1; \quad (62)$$

$$a = \sqrt[2.5]{\frac{E_1}{E_0}}; \quad (63)$$

$$b = \frac{a p k_{san}}{c E_0}; \quad (64)$$

- where
- H - thickness of single-layer covering, cm;
  - d - calculated diameter of the track of one pneumatic tire;
  - P - calculated load on one wheel, kgf;
  - p - operational specific pressure on the covering;
  - $g_1$  - internal pressure in the pneumatic tires of the aircraft, kgf/cm<sup>2</sup>;
  - $E_1$  - modulus of deformation of the material of single-layer covering, kgf/cm<sup>2</sup>;
  - a - coefficient depending on the quality of the materials being used, taken according to Table 51;
  - $\alpha$  - conversion factor to deformation, which causes the initiation of fracture of covering, taken according to Table 52;
  - $K_{san}$  - the strength reserve factor of the covering, taken for starting sections of RW, RD and MS equal to 1.5; for the middle sections of RW - 1.3;
  - c - coefficient which considers the loading effect from wheels on the aircraft strut (it changes within 0.6-0.8); for strut with single pneumatic tire  $c = 1$ .

Table 51

$E_1$ , kgf/cm <sup>2</sup>	a	$E_1$ , kgf/cm <sup>2</sup>	a
600	0.979	1300	0.968
700	0.983	1400	0.967
800	0.983	1500	0.967
900	0.983	1600	0.967
1000	0.983	1700	0.967
1100	0.983	1800	0.967

Table 52

Calculated diameter of pneumatic tire track, cm	Calculated value of coefficient $\alpha$
25	1.8
25-30	1.6
31-35	1.5
36-45	1.4
45	1.3

The computed value of the modulus of deformation of soil  $E_0$  is taken on the basis of results of field soil tests or by Table 53.

Table 53

Soil	Climate zone			
	II	III	IV	V
	Calculated modulus of deformation, kgf/cm <sup>2</sup>			
Fine sandy loam	200	250	275	250
Extra-fine sandy loam and sandy-silty soils	150	175	250	200
Loam	125	150	200	250
Heavy loam, clay	110	130	200	250
Silty loam and silty sandy loam	100	125	175	200

The calculation of two-layered coverings is performed also using the formulas given above. In this case the thickness of the top layer is designated constructively and is refined by calculation taking into account the modulus of deformation of the material of the top layer.

## CHAPTER IX

### STORM SEWER SYSTEM AND DRAINAGE NETWORK OF ARTIFICIAL COVERINGS OF AIRFIELDS

#### § 40. PURPOSE

The artificial coverings of RW, RD and MS are subjected to the intense effect of aircraft loads. The strength and stability of the coverings is ensured only with sufficiently high bearing capacity of the soils of bases, which is sharply lowered with overmoistening of the soils. Thus, with overmoistening of soils their modulus of deformation (substratum coefficient) can be decreased 30-40%, which will lead to an inadmissible reduction in the strength of coverings. The overmoistening of the soils of bases can occur because of the infiltration of water through the body and joints of coverings and as a result of the capillary rise of the level of ground water. For the prevention of overmoistening of the soils of bases and the verges of artificial coverings there is constructed storm sewer and drainage network. With their aid are collected surface (downpour, thawed) waters, which drain from the covering, verges and from soil catchments adjacent to coverings, and they are carried away outside the airfield; surplus water is carried away from the draining bases of artificial coverings; the level of ground water and prolonged autumn vadose water is lowered; the ground waters, which proceed under the artificial coverings from the adjacent sections of the flying field are captured.

With the construction of storm sewer and drainage network there should be solved the principles of its operation, layout in

the plan, longitudinal sections, and there should be determined the calculated flow rates of water, the dimensions and constructions of drains and structures.

#### § 41. PRINCIPLES OF OPERATION

The selection of the basic principles of operation of storm sewer and drainage network of artificial coverings is accomplished depending on the climate, hydrogeological and topographic conditions of the airfield location. Upon consideration of these conditions there can be two solutions: storm sewer and drainage networks are not constructed with artificial coverings or are constructed selectively; artificial coverings are equipped with a complete system of storm sewer and drainage networks. The first solution relates to cases of location of the airfield in an arid zone or in other zones with the presence of well filtering soils (sands, sandy loams). With the absence of draining systems or with their selective construction on low sections of RW, RD and MS (for example at the places of their passage through natural thalwegs) the disposal of water is accomplished to the soil sections of the flying field or to soil troughs with the slope of the ground surface toward the coverings. The second solution is used with necessity of the removal of surface and ground waters from the artificial coverings of RW, RD and MS at airfields located in the zones of excess and variable moistening or in the zone of insufficient moistening on clay, loamy and heavy sandy loam soils. For protection of the artificial coverings from the draining water from adjacent catchments the edges of coverings should be raised above the adjacent ground surface of the flying field not less than 30-50 cm, and along the coverings we construct soil verges with slopes from coverings not less than 0.015.

In necessary cases from the highland side for the capture of surface waters we construct soil troughs, along the bottom of which are laid water-receiving thalweg wells. At the location of

the airfield in zones of overmoistening, variable or insufficient moistening on loamy and clay soils, with slope of troughs less than 0.0050 along their axis are laid pipe dryers.

If on the separate sections of the flying field, adjacent to artificial coverings, there are closed low places, then in them are installed water-receiving thalweg wells.

For the disposal of surface water along artificial coverings we construct open troughs, rain-gully wells and overflows to underground collectors, which discharge the water outside the boundaries of the airfield.

With location of the airfield in zones of excess, variable or insufficient moistening with loamy and clay soils there should be provided removal of water from artificial bases with the aid of edge drains. The draining base of the underlying layers in this case leads to the drains. The water from drains is delivered into the manholes of the collectors, applied along the coverings. Edge drains cannot be constructed in an arid zone or in other zones when sand or sandy loam soils exist.

If on the section of the location of the airfield the level of ground water is high or prolonged autumn vadose water is observed, it is recommended along the edge of coverings to construct deep drains. These drains are used for the removal of water from artificial bases.

On sections with high level of ground water or with prolonged vadose water deep drainage should be constructed. Deep drainage should ensure lowering of the level of ground water taking into account the construction of embankments under the covering to a magnitude determined by the characteristic of the soil of the natural base of covering and by the climate zones, in which the airfield is located.

The minimum rise of the bottom of the trough above the level of ground waters depending on the soils of the natural base of covering and climate zones of the location of the airfield is changed from 0.5 to 2.0 m, which was stated above.

For the capture of ground waters, which proceed under the artificial coverings from the adjacent sections of the flying field, along the edges of the covering deep protective banks are constructed.

All constructions of the storm sewer and drainage network - thalweg wells, water-receiving wells, edge drains and pipe dryers, deep banks - are connected to collectors, layed along the edge of the covering. Water through the collectors is removed outside the boundaries of the airfield and is disposed into ravines, rivers, lakes.

#### § 42. SCHEMES OF STORM SEWER AND DRAINAGE NETWORKS

The schemes of construction of storm sewer and drainage networks are developed during the project of vertical planning. In the absence of storm sewer and drainage networks (in an arid zone) the scheme of draining depicted on Fig. 51 is characteristic. The disposal of water is accomplished into the verge, reinforced by paving, and into the soil trough, located 15-20 m from the verge of the covering. On the bottom of the soil trough are placed manholes with grated covers, exiting to the surface, or thalweg wells. Manholes or thalweg wells are connected to collectors, which remove water outside the boundaries of the airfield.

The scheme of draining with the presence of storm sewer and drainage network with coverings of the airfield is depicted on Fig. 52. The draining system includes: open troughs, rain gullies, edge drains, thalweg wells, soil troughs, overflows

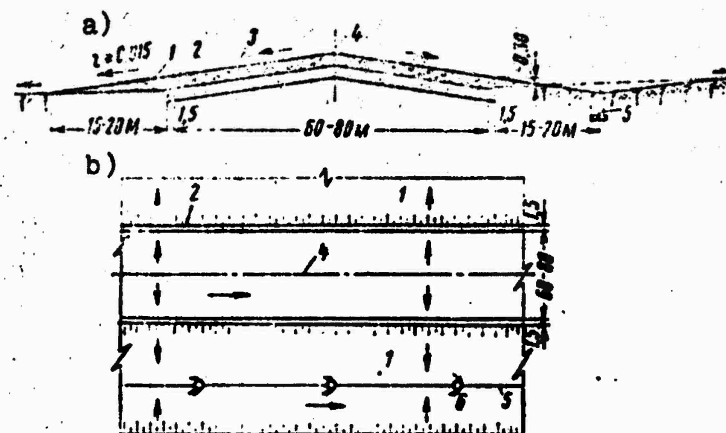


Fig. 51. Scheme of draining in the absence of storm sewer and drainage networks: a) cross section; b) layout; 1 - piled-up soil; 2 - paving; 3 - covering; 4 - axis of runway; 5 - collector; 6 - manholes.

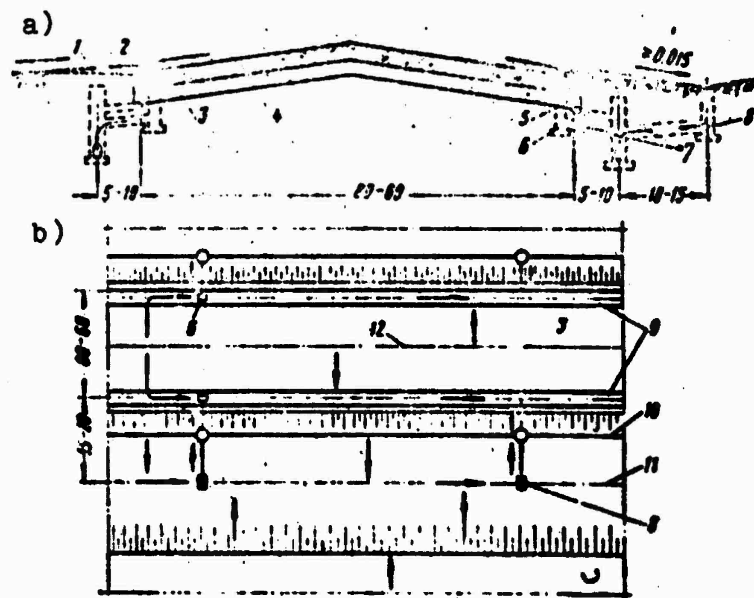


Fig. 52. The scheme of draining with the equipping of coverings with storm sewer and drainage networks: a) cross section; b) layout; 1 - piled-up soil 2 - axis of collector; 3 - sand base; 4 - concrete covering; 5 - edge drain; 6 - rain gully; 7 - overflow; 8 - thalweg rain gully; 9 - open troughs; 10 - runway collector; 11 - axis of soil trough; 12 - axis of runway.

collectors, main collectors, main channels, mouth constructions. If the artificial coverings of RW and RD are designed with ridged surface profile, open troughs and collectors are constructed on two sides of the coverings; if the coverings have single-slope profile, the storm sewer network is constructed on one lower side.

With the presence of high level of ground or vadose waters there are additionally laid deep drains and banks.

Open troughs serve for the direct reception of surface waters which drain from coverings and their removal into an underground network. Troughs on the edges of coverings have a triangular cross section and approximately the following dimensions: for RW with single-slope profile - width 5 m, depth 10 cm; for RW with ridged profile - width 4 m, depth 8 cm; for RD - width 2.4-3.0 m, depth 8 cm.

If border thickenings are necessary their width is taken as 0.8 m, depth - 8 cm.

For group MS of aircraft and other areas of coverings the dimensions of troughs are determined by calculation depending on the magnitude of catchment area and on the average there is taken width 4-5 m, depth 8-10 cm.

The longitudinal slopes of open troughs should be not less than 0.0025. If artificial coverings do not have the required longitudinal slope, the bottom of open troughs is given a serrated profile with minimum longitudinal slope 0.0025.

Rain gullies are intended for the reception of surface water collected by troughs, and its overflow into the drain collector. Rain gullies are constructed on the bottom of open troughs and in all the low places of coverings. The distance between rain-gully wells in troughs is assigned depending on the calculated rain force and the type of covering according to Table 54.



Table 54

Longitudinal slopes of the bottom of troughs	Ridged RW and areas with coverings with length of catchment 25-30 m	Single-slope RW and areas with coverings with length of catchment 50-60 m		Ridged and single slope RD
		Calculated rain force, mm/min		
		2-3	3-4	
0.0025-0.005	100-150	100-125	75-125	100-150
Over 0.0050	150-200	125-175	125-150	150-250

Note. In all other cases, not indicated in the table, the distance between rain-gully wells is taken not more than 200 m.

Rain-gully wells are constructed of normal and reinforced type; reinforced rain gullies are constructed when the slopes of open troughs exceed 0.005.

The troughs equipped with thalweg wells capture ground water from the catchments adjacent to coverings. Troughs and thalweg wells are constructed so as to eliminate any possibility of flooding of artificial coverings. The distance between thalweg wells in troughs is taken as the following: with slopes of troughs up to 0.005 - 100 m; with slopes more than 0.005 - to 200 m.

Thalweg wells are located perpendicular to the thalweg. If on the bottom of soil troughs we lay pipe dryers, with the slope of troughs less than 0.005 the dryers are given a slope not less than 0.003, and their length is taken as 100 m.

The edge drains, being laid along the coverings, drain the water from artificial bases with the aid of overflow into collectors. Edge drains are layed along coverings at a distance of 1.0-1.5 m from their edge. Standard data on the

construction of drains, including for deep drainage (the distance between drains, slopes and others), are similar to data taken when draining soil strips of the flying field and are examined above.

For the removal of water, gathered from artificial coverings and adjacent catchments outside the boundaries of the airfield, the network of collectors is constructed taking into account the following requirements: collectors are placed 5-10 m from the edge of the coverings; the quantity of intersections of collectors with artificial coverings should be minimum; the slopes of collectors should ensure pipelines not filling up with mud and eliminate the appearance of velocities dangerous for butt joints, the slopes of collectors should be not less than: for pipes up to 300 mm in diameter 0.002-0.003, for pipes 300-500 mm in diameter 0.001-0.0015. The slopes of the overflow from rain-gully wells are 0.02-0.03. The slopes of the overflow from thalweg wells are 0.005-0.020.

On collectors there is provided the construction of manholes at their beginning, on turns, with change of slopes, on connections to the collectors of overflows from rain gullies or other drain lines; the distance between manholes on the straight sections of collectors depending on the diameter of the pipes are taken: up to 250 mm - 50 m; from 250 to 400 mm - 75 m; from 400 to 600 mm - 100 m and over 600 mm - 125 m.

For determining the depth of laying of the collectors the pipes are calculated for strength from the action of aircraft loads. It is inexpedient to take the depth of laying of the collectors less than the depth of freezing, since in this case breakages of pipes are possible during thawing and swelling of the soil.

The places of water discharge from collectors (open channels or water intakes) are equipped with mouth constructions (caps), the requirements for construction of which are similar to those examined above.

#### § 43. STRUCTURAL ELEMENTS OF STORM SEWER AND DRAINAGE NETWORKS

Open troughs (Fig. 53a) on RW have triangular cross section and are constructed from the same materials as the covering. At the mating places of the troughs with the soil surface of the flying field there is constructed paving. Curb thickenings on RD are made in the form of the construction depicted on Fig. 53b. On the mating section of the curb thickening with the soil paving should also be mandatory.

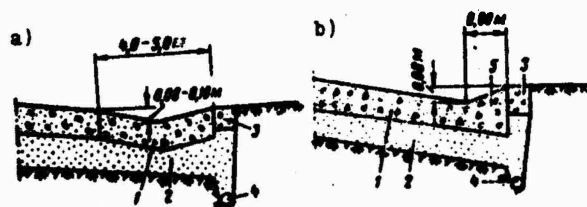


Fig. 53. Constructions; a) open trough on RW; b) curb thickening on RD; 1 - covering; 2 - base; 3 - paving; 4 - edge drain; 5 - curb thickening.

Rain-gully wells (Fig. 54) are of the normal and reinforced type. The first type of wells (Fig. 54a) is constructed on RW and soil MS with longitudinal slope of open troughs less than 0.005 and with any longitudinal slopes (on RD and individual MS).

The second type of wells is constructed if the longitudinal slopes of open troughs exceed 0.005. With the slope of the troughs from 0.005 to 0.007 we use the construction depicted on Fig. 54c, and with slope more than 0.007 - the construction depicted on Fig. 54b.

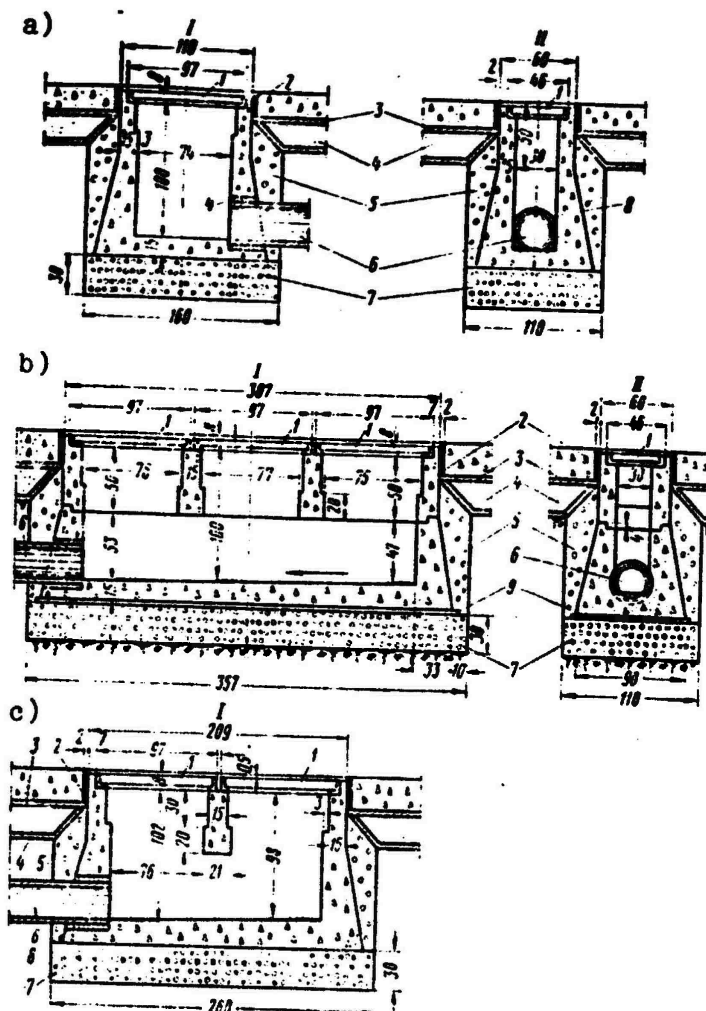


Fig. 54. Construction of rain-gully well: I - cross section across the runway; II - cross section along the runway; 1 - lattice; 2 - bitumastic; 3 - layer of grease-proof paper; 4 - insulation layer of sand, treated with bitumen; 5 - water-resistant soil; 6 - overflow pipe; 7 - slab bed; 8 - lining of tarred hemp 1-1.5 cm thick; 9 - cement mortar of composition 1:6-1:8.

In all cases the depth of the rain-gully wells from the bottom to the top of the supporting frame is taken as 1.0 m. Rain-gully wells are installed with the long side perpendicular to the axis of the open trough. The wells can be of precast and cast in-situ construction. The concrete used for the manufacture of rain-gully

wells should have grade not below 200 and reinforcement from steel of class A-I. The lattices and supporting frames of the rain gullies are also manufactured from steel of class A-I. The bottom of water intakes is installed on a slag bed.

At the places of joining of the rain gullies with artificial coverings and overflows there should be provided reliable water-proofing from bitumastic, grease-proof paper and insulation layer of sand treated with bitumen. The clearance between the openings of overflow in the rain-gully well and the external diameter of the overflow pipe 1.0-1.5 cm is thoroughly packed with tarred oakum.

When building the artificial coverings of swelling soils we use special constructions of rain-gully wells of fine laying (Fig. 55), providing identical rise in the swelling of wells and coverings. The rain gully of such a construction consists of reinforced-concrete troughed slab, coupled with the artificial coverings, and storm sewer devices - cellar metal lattices and vertical branch connection in the bottom.

The branch connection with the aid of elastic joining (lining of tarred hemp) is connected with a welded elbow of steel pipes with anticorrosive coating, into which goes the asbestos-cement overflow pipe. The welded elbow is connected with the overflow pipe with the aid of a joining coupling. At the places of coupling of the reinforced-concrete troughed slab with the soil surface of the flying field on the verge is constructed a crushed stone covering by the method of impregnation with bitumen 6-8 cm thick.

The manholes, intended for cleaning and repair of the storm sewer network, are constructed similar to the constructions of wells of the drainage network of the flying field. During the connection of collectors with the main sewers the manholes are equipped with sediment tanks. Thalweg rain-gully wells are

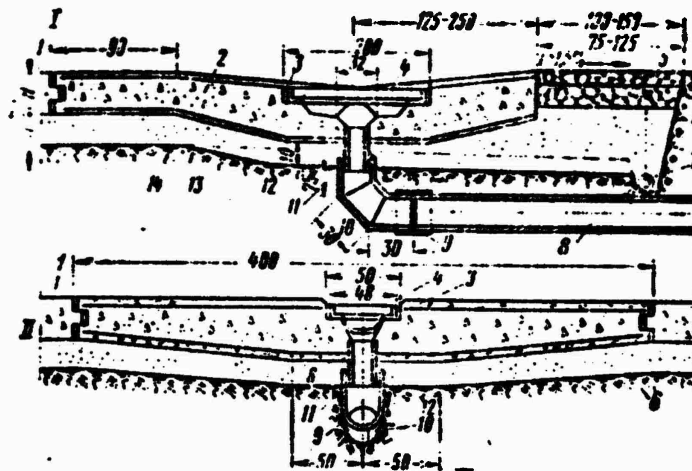


Fig. 55. Construction of rain-gully well of fine laying for the runways: I - cross section across runway; II - cross section along runway; 1 - covering; 2 - reinforced-concrete troughed slab. 3 - framing of slots with cement mortar of composition 1:3; 4 - lattice; 5 - crushed stone covering of verge with bitumen impregnation to a depth of 6-8 cm; 6 - sand base; 7 - edge drain from earthenware pipes 50-75 mm in diameter; 8 - asbestos-cement overflow pipe; 9 - joint coupling; 10 - welded elbow from steel pipes with anti-corrosive coating; 11 - lining of tarred hemp; 12 - insulating layer of bitumastic; 13 - surface of the bottom of the trough under troughed slabs; 14 - surface of the bottom of the trough under slabs with rain-gully funnels.

constructed with 1 m depth from the bottom of the supporting frame to the bottom. On the bottom of the well with slope to the overflow pipe we constructed a concrete trough. The construction of the thalweg well of the storm sewer network of artificial coverings is carried out analogically with the construction of the well of the drainage network of the flying field. The dead-end chambers (connections with no well) are used for the connection of overflows to collectors at places where manholes are absent. With the outer diameter of the collector pipes up to 500 mm we construct dead-end chambers with internal dimensions in the plan not less than  $0.7 \times 0.7$  m (Fig. 56). With large diameters of collector the internal dimensions of the dead-end chambers are increased 3-5 cm as compared with the outer diameter of pipes. The bottom and walls of the chambers - concrete, and the cover - reinforced-concrete slabs.

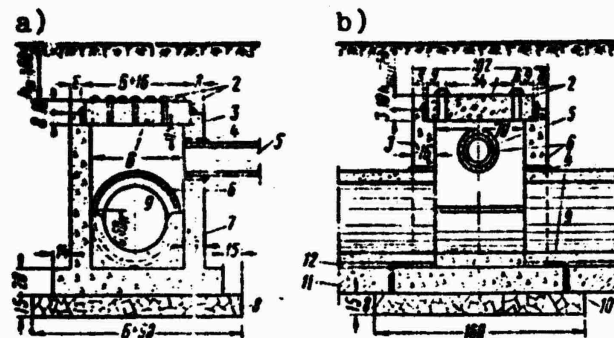


Fig. 56. Construction of dead-end chamber: a) cross section across runway; b) cross section along runway; 1 - cover with openings; 2 - framing of openings with broken clay; 3 - concrete wall of the chamber; 4 - insulation with bitumen; 5 - overflow; 6 - lining of tarred hemp 1-1.5 cm thick; 7 - concrete trough; 8 - crushed stone preparation; 9 - pipe of collector; 10 - expansion joint; 11 - concrete or reinforced-concrete base; 12 - levelling layer of cement mortar of composition 1:3.

The main collectors, main and high ditches, mouth structures have the same constructions when draining the flying field, examined above.

When designing the storm sewer and drainage networks of the artificial coverings of airfields there should be performed hydraulic and strength calculations of the elements of the network, the basic principles of which are examined above.

## CHAPTER X

### METAL COVERINGS OF AIRFIELDS

#### § 44. AREA OF APPLICATION

Metal coverings are used on temporary airfields to provide short-duration operation of aviation, mainly during the spring and autumn bad road periods, when due to the overmoistening of soils and as a consequence of this the loss of bearing capacity, flights from unpaved airfields become impossible.

Today for the operation of modern aircraft only the metal coverings made of steel stamped plates are suitable. They allow assembly and dismantling in short periods, estimated in several days, with any weather and any state of soil base - water-saturated, frozen and dry.

The basic requirements imposed on metal coverings are: strength and reliability during the bad road period. i.e., with the lowest bearing capacity of the soil; evenness and sufficient roughness at any moistening of the surface, which facilitates the aircraft braking during the landing run after touchdown; good cohesion with the soil; minimum weight; minimum quantity of separate elements; the possibility of repeated use of each element; the possibility of application of industrial methods during the construction of coverings; the possibility of transportation of plates by trucks; the realization of installation and disassembly



with the aid of small-scale mechanization means; the possibility of increase in the bearing capacity of coverings with the reinforcement of metal plates to packed soil bases.

#### § 45. CONSTRUCTIONS OF METAL PLATES

Stamped steel perforated plates are manufactured from steel plate 3.5 mm thick with dimensions in the plan 3041 × 411 mm, weight of plate 33 kg, and weight of 1 m<sup>2</sup> of covering made from such plates - 27 kg.

Three rows of openings 66 mm in diameter reduce the weight of the plate and facilitate the drying out of soil under the covering. For increase of the cohesion of the plate with soil and increase of its rigidity the ends of the openings are flared, and the plate has a shaped profile with two longitudinal grooves 21 mm high (Fig. 57). For the connection of plates along the longitudinal edges of the plate there are hooks and slots. During assembly of the covering the hooks of one plate enter the slots of the adjacent plate; we further shift the plates along the locks until the hooks do not go beyond the edges of the slots, whereupon into the freed place of the slots we place 2-3 spring metal clips (Fig. 58). The clips do not let the plate move back and disengage the hooks.

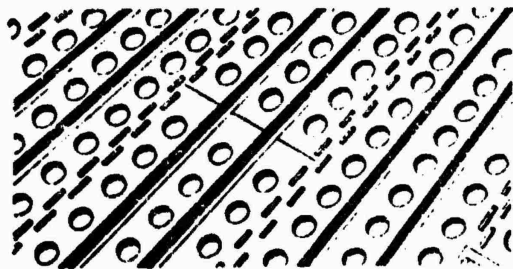


Fig. 57. Coatings made from steel perforated plates.

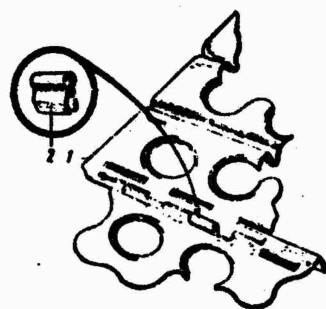
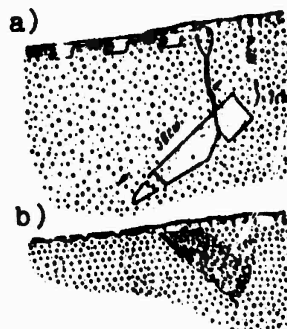


Fig. 58. Connection of the perforated plates: 1 - covering plate; 2 - spring clip.

Coverings are assembled so that the plates are placed with the long side perpendicular to the longitudinal axis of the flying strip. In order to provide uniform strength of the covering, the joints of the plates move to the middle of each plate. For levelling the covering along the edges in longitudinal direction through a row on each side there are placed half-plates.

The edges of the plates are attached to the soil with the aid of wire twist joints and wooden stakes (Fig. 59a). On end sections of RW the extreme four rows of plates are put into the soil at a 35-45° angle; with this the last row is fastened by stakes, whereupon back filling with soil is accomplished (Fig. 59b). The fastening of plates at the longitudinal edge and on the RW ends is necessary for the prevention of the rise of plates with the passage of aircraft wheels. For the removal of plates which require repair or replacement from the covering it is necessary to remove the clips, shift the plate and disengage the hooks from the slots of adjacent plates.

Fig. 59. Attachment of the edges of plates: a) at the longitudinal edge; b) at the end of the runway.



The operating experience showed that the metal coverings made of metal perforated plates have a number of shortcomings and provide operation of aircraft with takeoff weight only up to 15 t in the bad road period. During the operation of such coverings by heavier aircraft there were observed failures of scarf joints, deep tracks, inadmissible bending back of the edges of plates. The openings in the plates complicated the operation of aircraft, since the overmoistened soil was squeezed from the openings, getting into engines, and around the openings were formed local settlements, leading to inadmissible deformations of plates.

For elimination of the indicated shortcomings the steel plates were constantly improved and today besides perforated plates there is a number of other types. The technical characteristic of such steel plates is given in Table 55.

The MPP and MPP-1-53 plates have perforated openings 50-66 mm in diameter. The plates are connected by standard locks, which consist of hooks and slots, which are engaged with horizontal shifting; the locks are fastened by spring chains. The MP-1-51, MP-2-51 plates do not have through perforation; MP-2-51 plates possess increased strength. The K-1-D metal plates (Fig. 60), developed by M. I. Buryakov, V. V. Yermolov, M. A. Vasilevskiy, B. V. Pugachev and G. I. Glushov, have a number of advantages as compared with all other plates. They possess the greatest strength, the openings in them are replaced by spherical bulges along the lower and upper flanges; they are connected with the other plates along the whole perimeter; individual plates can be removed from the covering. On the faces the edges of adjacent plates are superimposed on each other and are fastened by two steel clamps. The clamps enter the end slots of adjacent plates and are bent back by light taps of a hammer. The connection of plates on the faces, characteristic only for K-1-D plates, considerably improves the operating conditions of the plate with

Table 55

Indexes	Types and designations of plates				
	MPP	MPP-1-53	MP-1-51	MP-2-51	K-1-D
Overall dimensions, mm:					
Length	3041.5	3042.4	3042.4	3034.0	3080.0
Width	411	411	411	436	482
Height	21	21	21	23	23
Thickness of sheet, from which the plate is made, mm	3-3.5	3.0	3.0	2.5	3.0
Weight of the plate, kg	27-32	28	30	30	42
Moment of resistance, cm <sup>3</sup>	1.98-2.27	2.00	2.00	7.80	14.10
Possibility of removal from the covering	Is removed	Is not removed	Is removed		
Connection of plates	With the aid of chips		Without clips		
Packing dimensions, mm:					
Length	3048	3048	3048	3040	3000
Width	381	381	381	390	420

overmoistened soil, and it also improves the work of aircraft wheel casings, since edge joints do not allow the bending back of the ends of the plates, which damages the casings, which takes place in all the remaining constructions of steel plates.

During the short-duration operation of aviation the metal plates are placed on a natural soil base. The base should be preliminarily laid out and well consolidated. It is advantageous

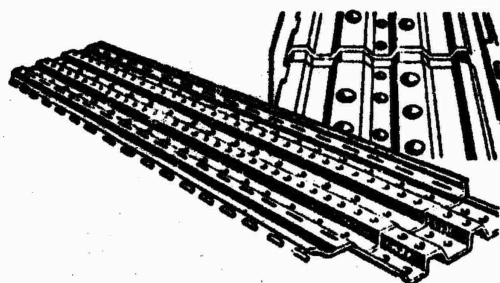


Fig. 60. Metal plates of increased strength with reinforced scarf joints.

to place the metal plates on sandy loam and loamy soil base with sod cover. With the placement of steel perforated plates on noncohesive and on bare soils (without sod) preliminarily on the soil surface we place rolled materials, straw, hay, as a result of which squeezing of the soil through the openings in plates does not occur.

For increase of the bearing capacity of metal coverings it is possible to place the metal plates on soil earth and crushed rock bases and also on soil bases treated with binding materials. The assembly of metal plates on the RW covering can be performed with diverging, converging and running-on fronts (Fig. 61). With the diverging front the works are begun on the clamps from the middle cross section and finished on the edges. With converging and running-on fronts it is necessary to connect the plates with joining of the fronts, which requires the spreading or the tightening of plates, which cause difficulties when stacking. These difficulties are absent when working according to the scheme of the diverging front, therefore the given method of assembly of the covering is the most effective. The plates are assembled into a bond, by shifting them half in rows; at the end of the rows are placed half-plates. Installation operations of plates are finished by the attachment of the covering along the longitudinal edges and ends of the runway.

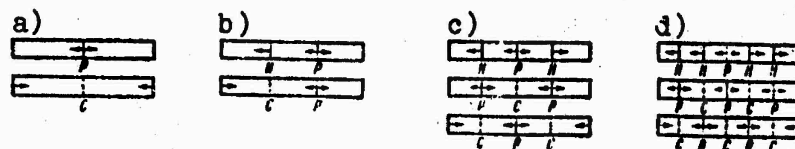


Fig. 61. Assembly diagram of metal plates on the RW covering: a) two fronts of assembly; b) three fronts of assembly; c) four fronts of assembly; d) six fronts of assembly; P - diverging front; C - converging front; H - running-on front.

During the assembly of metal coverings special attention should be given to the quality control of operations, and in particular, to check of the tightness of the joining of the covering to the base. For the close fitting of plates to the base it is necessary that it be well laid out. During the check of the evenness of the base with a 3-meter rod the clearance should not exceed 10 mm. The sagging of separate sections of the assembled plates is inadmissible.

During the installation of plates there is performed geodetic checking of the perpendicularity of the placement of plates to the longitudinal axis of the covering. For the correctness of placement of each row of plates a check is performed with the aid of a string, taught across the runway ends. The deviation of the edges of the placed plates from the string should not exceed 5 cm for each 100 m of RW length. Driven in clips, edge clamps, the reliability of weld seams and wire twist joints on RD and RW connections will be subjected to quantity control. Before putting into operation the covering should be tested by the passes of loaded MAZ-200 or ZIL-150 automobiles along and across the RW. The metal covering is put into operation when during the maximum running speed of automobiles and their sharp braking no defects of the connection of plates and attachment of edges are detected.

## CHAPTER XI

### SNOW AND ICE COVERINGS OF AIRFIELDS

#### § 46. AREA OF APPLICATION

Snow coverings are constructed by the snow packing method. Snow coverings are advisable in areas with stable minus air temperatures on soil RW, RD and MS, designed for operation by recip aircraft. In areas with unstable minus air temperatures the snow is packed during the construction of the side clear zones and overruns of airfields.

The snow coverings should ensure the execution of takeoff and landing operations of aircraft without interruption. On the snow coverings is imposed a number of requirements; the main ones - sufficiently high hardness or bearing capacity, which is determined by the ability of snow to withstand a load from the aircraft wheels. For the operation of winter airfields the bearing capacity of snow coverings should be not less than  $7 \text{ g/cm}^2$ . It is attained with the high density of the packed snow, i.e., not below  $0.5 \text{ g/cm}^3$ . In the areas with unstable minus air temperature even the well packed layer of snow is cut through during thaws by pneumatic tires and impedes takeoff and landing. Therefore for the safe operation of modern aircraft the thickness of the packed snow in areas with unstable temperatures should not exceed 10 cm in a dense body. It is necessary to remove the

excesses of freshly fallen snow from the packed snow covering. In the areas with stable temperatures below the freezing point the thickness of snow covering is not limited.

Ice airfields on sea basins are constructed in bays and lagoons, shielded from flows and winds. On lakes and rivers the most convenient are shallow bays (with depth up to 2-4 m), for which the small rates of flow and fluctuations of the water level are characteristic, which contributes to more uniform ice formation with an even surface and high strength. Ice sheet on the flying field of the airfield should possess sufficiently high bearing capacity, which is determined by the thickness of ice, its uniformity and strength. The necessary thickness of the covering is determined by calculation depending on the takeoff weight of the aircraft based there. The ice covering should have an even surface without cracks, current holes, clearings, hummocks and glaze.

#### § 47. BASIC PROPERTIES OF SNOW, ICE AND COVERINGS MADE FROM THEM

Depending on age and properties the snow is subdivided into the following forms: freshly fallen, which retains the primary crystal shape of a snowflake; not fresh, having already partially changed the original structure under the influence of settling, evaporation, wind; old, having completely changed form and consisting of large crystals of grains. The basic properties of the snow cover include density, thickness, duration of lying and bearing capacity. The density of freshly fallen snow is  $0.03-0.2 \text{ g/cm}^3$ , not fresh - from  $0.2$  to  $0.4 \text{ g/cm}^3$ , old - from  $0.3$  to  $0.5 \text{ g/cm}^3$ . As can be seen, freshly fallen, not fresh and old snow does not satisfy the requirements for density, which are imposed on snow coverings.

The thickness of the snow cover depends upon the climate zones, relief and state of the earth surface. The average thickness of



the snow cover in the territory of the central part of Europe is more than 50 cm and reaches 90 cm on the western slopes of the Ural range. On the south west the thickness of snow cover is decreased, on the coast of the Black, Azov and Caspian Seas it is less than 10 cm. In western Siberia the thickness of snow cover reaches 100 cm; in eastern Siberia the thickness of snow cover is decreased to 30-10 cm.

The duration of the lying of snow cover is extremely diverse: to the south it is 20 days, in the central section approximately 150 days, in Siberia it exceeds 200 days a year, to the north 260 days. At temperatures close to zero snow cover of even greater density loses bearing capacity. The bearing capacity of freshly fallen snow is small and even at temperatures  $-20^{\circ}$  does not exceed  $1 \text{ kgf/cm}^2$ .

Ice is a solid, into which water changes at temperature  $0^{\circ}\text{C}$ . Ice has a crystal structure; with prolonged frost the crystals intergrow. Ice of fresh bays possesses higher strength than the ice of salt basins.

The ice cover in most cases consists of three layers: black, turbid and bright ice. Black ice is the most durable; bright ice is weak. The properties of ice are determined by the rate of freezing, its uniformity, by the presence of hummocks, glaze, cracks, ice clearing. As a result of the incomplete freezing of water glaze can be formed on the ice. On the external surface there can be a layer of snow ice. The mechanical parameters of ice depend upon the temperature and its structure. The parameters which characterize the elastic and strength properties of ice are given in Table 56.

The properties of snow coverings depend upon the air temperature with packing of the snow cover, interruptions during packing, the age of snow covering.

Table 56

Indexes of ice	Value of index		Mean Value
	minimum	maximum	
Modulus of elasticity during compression, tension and bending, kgf/cm <sup>2</sup> ;	4300	92,700	30,000
Rupture stresses of ice, kgf/cm <sup>2</sup> , during:			
Compression	12.0	127.0	30.0
Tension	5.4	19.5	14.0
Bending	4.0	45.0	20.0
Shear	5.0	12.0	9.0

The bearing capacity of the snow cover is greater, the higher the density  $\rho$  and the lower its temperature (Fig. 62). As is apparent, only snow of high density ( $0.5 \text{ g/cm}^3$ ) at a temperature below  $-15^\circ\text{C}$  satisfies the standard requirements, imposed on the snow coverings. With density  $0.4 \text{ g/cm}^3$  the bearing capacity  $7 \text{ kgf/cm}^2$  will be achieved at temperature not higher than  $-30^\circ\text{C}$ . The analysis of relationships shows that to obtain large bearing capacity there is necessary high density of the snow cover, which is attained at a certain temperature. Density  $0.55\text{--}0.58 \text{ g/cm}^3$  can be obtained at temperatures close to zero; at low temperatures ( $-20^\circ\text{C}$ ) it is difficult to pack the snow more than up to  $0.46\text{--}0.48 \text{ g/cm}^3$ .

An increase in the snow density is attained when the load is applied with interruption in time. Thus, if after each loading we set up four-hour interruption, it is possible to obtain the same density as after 10 loadings, but without a time interval.

The basic properties of snow coverings should include a rise of their strength with time (Table 57).

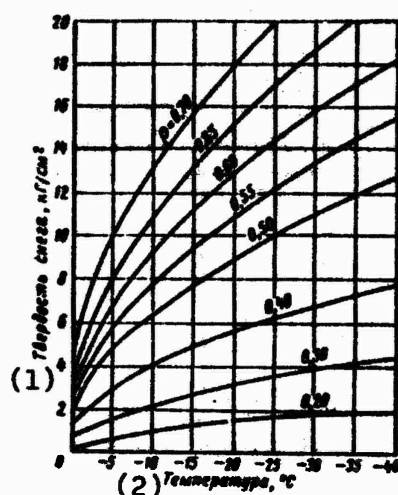


Fig. 62. Relationship of the bearing capacity of snow coverings to the density and temperature.  
KEY: (1) Hardness of snow,  $\text{kgf/cm}^2$ ;  
(2) Temperature,  $^{\circ}\text{C}$ .

Table 57

Time, h	Number of passes			
	1	3	5	10
	Bearing capacity, $\text{kgf/cm}^2$			
1	0.53	0.84	1.23	1.54
4	1.02	1.43	3.40	3.12
6	1.24	1.32	4.00	5.90
12	1.43	3.40	8.30	19.00

The strengthening of the snow coverings as a result of packing, and also with time occurs because of the complex processes of the evaporation of snow and precipitation of water vapors into crystals, proceeding under the action of pressure and temperature. The thickness of ice coverings should ensure the safe operation of aircraft.

Freshly fallen snow on ice coverings can be cleaned or packed. With cleaning on the surface of the ice covering there is left a protective layer of snow 3-5 cm thick, which, freezing together with the ice cover, protects it from solar rays and

creates the rough surface necessary for cohesion with the pneumatic tires of the aircraft wheels. With the packing of snow on ice the same requirements are imposed as during the construction of snow coverings on ordinary unpaved airfields. Ice airfields allow operation before the beginning of ice thawing and the appearance of thaw water on the ice covering.

#### § 48. PRINCIPLES OF THE STRENGTH CALCULATION OF ICE COVERINGS

During calculation the ice coverings are considered as plates lying on an elastic base, the substratum coefficient of which is equal to the specific gravity of water. The calculation is performed by the method of limiting states. As the limiting state of the covering there is taken the achievement of the breaking moment, which causes the opening of cracks on the bottom surface of ice. The permissible value of bending moment is found as a result of division of the breaking bending moment by the total safety factor, taken equal to two. Formulas for determining the required thickness of ice have the following form:

a) for fresh-water basins:

with mean air temperatures below  $-10^{\circ}\text{C}$  (winter days)

$$h_n = 16\sqrt{G}; \quad (65)$$

with mean air temperatures above  $-10^{\circ}\text{C}$  (spring days)

$$h_n = 22\sqrt{G}; \quad (66)$$

b) for sea basins:

in winter

$$h_n = 20\sqrt{G} - 0.25G; \quad (67)$$

in summer (old ice)

$$h_s = 1,5(20\sqrt{G} - 0,25G); \quad (68)$$

in summer (winter) fresh ice

$$h_s = 2(20\sqrt{G} - 0,25G). \quad (69)$$

where  $h_n$  - thickness of ice, cm;

$G$  - gross weight of aircraft, t.

For modern passenger aircraft the thickness of ice can be required not less than 2 m.

#### § 49. METHODS OF REINFORCEMENT OF ICE COVERINGS AND CONSTRUCTIONS OF SHORE SLOPES.

When the thickness of the ice covering is less than the required, determined by formulas, the ice cover is reinforced by method of laminar freezing with filling, ice, whose strength is approximately 30% less than the strength of natural black ice. Therefore when forming an ice crust the calculated thickness of ice coverings is determined taking into account the reduced strength of filling ice by formula

$$h_{p.s} = h_s + 0,7h_{n.s}, \quad (70)$$

where  $h_{p.n}$  - calculated thickness of ice, cm;

$h_n$  - thickness of natural ice, cm;

$h_{n.n}$  - thickness of frozen (poured-on) ice, cm.

Freezing is accomplished with air temperature from -8 to -20°C. At lower temperature in the frozen layer there appear fine cracks, which reduce the strength of coverings. The area is preliminarily cleaned and protected from the snow by rollers, which we wet with water and freeze. Then on the cleaned surface

of the ice cover we pour water in layers 0.5-1.0 cm with the aid of pumps from ice holes, located outside the flying strip. The duration of the crust formation of ice is determined by formula

$$t = \frac{790h}{T_0} \quad (71)$$

where  $t$  - duration of formation of poured-on ice, min;  
 $h$  - thickness of the layer of poured-on water, cm;  
 $T_0$  - absolute value of minus air temperature, °C.

Ice airfields should have reliable slopes from the shore to the ice. It is advantageous to arrange the sloping places on slanting shores (with incline not more than 10%). Ice should rest with edge on the shore. Frequently near the shore the thickness of ice is less than far from the shore, fractures, current holes and cracks are observed. In these cases we construct special artificial shore slopes. With height of the shore not more than 0.4 m the slope is made by freezing the ice, including brushwood or poles for the creation of a rough surface. With the height of shore more than 0.4 m and insufficient strength of ice, and also when the ice does not rest on the shore, shore slopes of one of three types are constructed: with foundation beam (Fig. 63a), crib (Fig. 63b) or with pile supports (Fig. 63c). Shore slopes are constructed wooden, from precast reinforced concrete (piles, sills, beams and slabs), according to the type of ordinary water-engineering constructions.

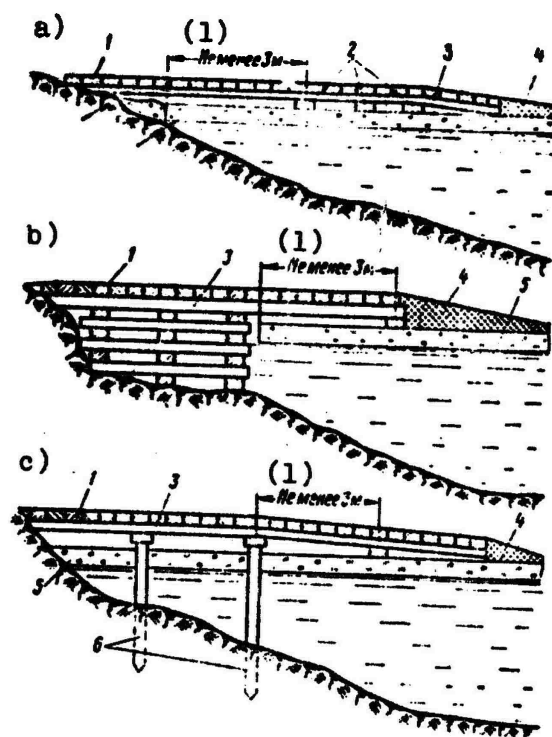


Fig. 63. Construction of shore slopes: 1 - flooring; 2 - foundation beams; 3 - joints; 4 - frozen ice with brushwood; 5 - ice; 6 - piles.  
KEY: (1) Not less than 3 m.

## CHAPTER XII

### AIRPORT LIGHTING AND ELECTRONIC EQUIPMENT

The flight of modern aircraft is accomplished with the aid of navigation instruments and radio navigation aids, which are aboard the aircraft, and also with the aid of visual observation of terrestrial reference points. At night or with poor visibility in the daytime the absence of visual orientation is compensated by the system of ground electronic and lighting aids.

Radio equipment allows aircraft to accurately enter the area of the airfield, to maneuver in this area, enter the landing course, descend for landing along a predetermined trajectory. The terminating stage of descent, touchdown, landing run on the RW and taxiing to the apron are facilitated by signaling aids.

Electronic and signaling aids are a sufficiently involved complex. The purpose and basic characteristics of these aids have been illuminated the most completely in the book by A. A. Bromberg, B. V. Grechishkin and others "Airport Mechanical and Energy Equipment," which are given below in compressed form.

#### § 50. LIGHTING EQUIPMENT

Under conditions of poor visibility in the daytime or at night the normal landing and taxiing of aircraft to the parking area are facilitated by signaling aids.



Three categories of signaling equipment of airfields are used: the system of high intensity (OVI); medium intensity (OSI); low intensity lights. The list of the lights used in these systems is shown in Table 58.

Table 58.

Signaling aids	Systems of light intensity			Signaling aids	Systems of light intensity		
	high	medium	low		high	medium	low
Elements of light equipment				Elements of the light mechanism			
Approach lights with pulsed light sources	+	+	-	Runway lighting	+	+	-
Fixed approach lights	+	+	+	Axis lights	+	+	-
Horizon lights	+	+	+	Touchdown zone lights	+	-	-
Threshold lights	+	+	+	Runway rapid departure lights	+	+	-
Barrier lights	+	+	+	Glide-path lights	+	+	+
Landing lights	+	+	+	Takeoff and taxiing signal lights	-	+	-
Touchdown sign lights	+	+	+	Light signaling for control of traffic along the airfield	+	-	-
Takeoff lights	+	+	+	Taxilights	+	+	+
Distance lights	+	+	+	Obstruction lights	+	+	+

\*Are installed selectively.

The system of high intensity lights is used, as a rule, in airports of the I and II classes, medium intensity - in airports of the III class, sometimes II class, low intensity - in airports of the IV and V classes, sometimes for airports of the III class and on airfields of local air lines.

The system of light equipment for the landing of aircraft includes approach lights, horizon lights, threshold lights,

barrier lights, landing lights, touchdown zone lights, runway lighting.<sup>1</sup>

The approach lights and horizon lights comprise the group of approach lights, they are placed in the territory of the approach area. The lights of this group indicate the direction of the RW axis and make it possible to establish the position of the aircraft relative to the touchdown point, and also to provide for the precise positioning of the aircraft on the landing course.

The approach lights are installed so that during the landing approach the pilot could refine the direction of motion of the aircraft and guide it to the landing course. Furthermore, they help him to change over from aircraft control by instruments to control by signaling aids.

The approach lights emit white light and they are located in the territory of approach corridors along a straight line, where the central row of lights is a continuation of the RW axis. The position of the straight line on which the light centers are placed must approach horizontal as much as possible and have the smallest possible inclination with respect to the level of the beginning of the RW.

With respect to the character of brightness the approach lights are divided into lights of constant radiation and lights with pulsed light sources. Approach lights of constant radiation are installed from the beginning of the RW to the inner marker beacon. They are single - up to 300 m from the beginning of the RW; dual - at a distance from 300 to 600 m from the beginning of the RW; triple - further than 600 m to the inner marker

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<sup>1</sup>Mogilevskiy D. A., Babkov V. F. and others. The Procuring and Planning of Airfields, M., Avtotransizdat, 1963.

beacon. In longitudinal direction the lights are placed every 25-50 m, in transverse - every 1.5-3.5 m.

Approach lights with pulsed light sources operate in the "running lightning" mode, i.e., they are lighted alternately one after another with pulsed frequency not less than 45 per minute. They are installed after the inner marker beacon on a length approximately 1500 m toward the outer radio station. The distance between the pulsed lights is from 25 to 50 m.

The horizon lights are also placed in the approach area. The horizon lights are intended for visual monitoring of the position of the aircraft in transverse direction by the pilot, i.e., they help to remove bank and level out the aircraft. This is attained by the construction of artificial horizon lights, emitting orange or white light.

The horizon lights are 3-5-6 rows of lights arranged perpendicular to the continuation of the RW axis and to the line of approach lights. The distance between rows of lights is 150 m, between lights in the rows - 2.7-3.5 m.

The light centers of each horizon light should be arranged on horizontal lines, perpendicular to the RW axis; in extreme cases there is allowed very insignificant deviation both in the plan and with respect to height. The extreme horizon lights are arranged on straight lines, which form apex angle  $3-4^\circ$ , whose apex coincides with the touchdown point of the aircraft on the RW;

Horizon lights in a complex with approach lights give the pilot the possibility of also determining the position of the aircraft relative to the runway edge at any moment of approach of the aircraft to the touchdown point.

The group of runway lights includes the light equipment, placed at the runway boundary and designed to facilitate takeoff and landing operations. This group includes threshold, barrier and runway lights, illumination lights, touchdown point indicator and illuminating instruments of landing lighting. The green threshold lights indicate the beginning of the runway. Their ignition means clearance to land. They are arranged along the ends of the RW, by installing not less than two lights on each side of the strip. Red barrier lights designate the end of the RW. Barrier lights with threshold lights turned off indicate the prohibition of landing. The lights are arranged along both ends of the strips not less than two on each side. Threshold and barrier lights are mixed in one row on a line perpendicular to the RW axis, alternately (Fig. 64). The distance between lights in the row 2.5-3.0 m (Fig. 64).

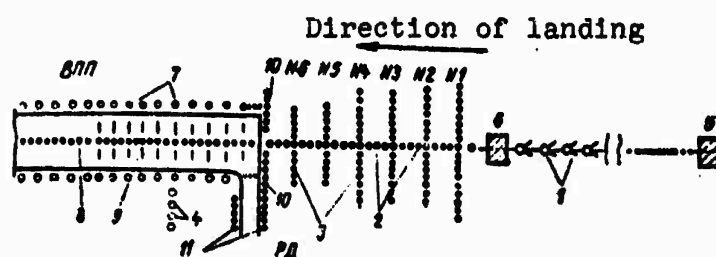


Fig. 64. Diagram of arrangement of the basic elements of the signaling equipment: 1 - pulsed approach lights; 2 - fixed approach lights; 3 - horizon lights (No. 1-No. 6 - the number of horizons); 4 - touchdown sign lights; 5 - outer marker beacon point; 6 - inner marker beacon point; 7 - landing lights; 8 - axis lights; 9 - touchdown zone lights; 10 - threshold and barrier lights; 11 - taxilights.

Landing lights are intended for marking the RW boundaries. They are placed approximately every 50 m along a straight line on both sides of the strip at a distance of 2-4.5 m from the edges. At the beginning and end of the RW on a length of 600 m on each side of it the landing lights have orange light filters. The

remaining lights, arranged in the middle of the strip, emit white light. The alternation of the colors of landing lights gives the pilot the possibility of determining not only the outlines of the RW, but also of evaluating on which section of it the aircraft is located.

The touchdown sign lights are used for amplification of the illumination of the edge sections of the RW and overruns, which helps the pilot to determine the altitude position of the aircraft immediately before touchdown. These lights are ordinary floodlight type and are installed on straight lines on both sides of the RW on the edge sections with extent 600 m and further to the end of the overrun. The lights are arranged in a second line behind the landing lights at a distance of 3 m from them. The distance in the row between the illumination lights located along the RW - 25 m, in the territory of the overruns - 50 m.

The touchdown sign lights serve for designation of the optimum touchdown point of the aircraft. The lights emit white light. They are installed on the left side of the RW (in the direction of landing) at a distance of 3-5 m from the edge of the strip and 150-300 m from its beginning. The position of the indicator should coincide with the touchdown point on the glide path. The touchdown point indicator is a combination of lights in the form of a horizon light, which consists of not less than four lights arranged perpendicular to the RW.

The enumerated lighting equipment does not provide sufficient RW visibility. For night landings the aircraft are equipped with landing lights, which illuminate the flying strip. In the case of the failure of aircraft headlights or their insufficient effectiveness we use stationary or portable ground illuminating instruments for runway and overrun lighting. For this we use airfield floodlight installations, which are placed on the left

and behind the touchdown or takeoff point of the aircraft so that the direct light of the floodlights does not affect the pilot's eyes.

The length of the illuminated landing area (light spot) should be not less than 200 m on the overrun to the runway edge and 250 m at the beginning of the strip.

All runway lights emit light from incandescent lamps and they are equipped with reflective and lens optics. As a rule we use ground type light. The height of the latter should not exceed 60 cm. All ground lights should have a weakened section in the base of the construction and be easily tipped over with accidental touching of them by aircraft wheels.

The scanning lights are intended for indication to the pilot of the general outlines of the RW and the direction of landing during night flights in a circle under conditions of good or impaired visibility. For these purposes the scanning lights are installed on the approach lights (constant radiation and with pulsed light sources), on threshold, barrier and landing lights. The scanning lights, installed on approach lights and barrier lights, emit red or white light; on threshold lights - green light, on landing lights, placed on 600-meter edge sections of the RW - white-orange light and on remaining landing lights - white light.

Takeoff signal lights have the purpose of permitting (green light) or prohibiting (red light) the takeoff of aircraft, which taxi to the takeoff area. Signal lights are installed at the RD exit to the RW, at its beginning at a distance of not less than 30 m from the edge of the strip and 10-12 m from the left edge of the RD. The height of the signal light is not more than 60 cm; its light should not be visible to the pilots of the landing aircraft.

Taxilights are intended for indication of the RD boundaries. They are arranged along the edges of the artificial covering and placed according to the type of RW landing lights, but with radiation of blue or green lights. The lights are placed on both sides of the RD every 25-50 m. On the RD are installed signal lights where the RD intersects the runways or taxiways.

The airfield obstruction lights designate high obstacles within the territory near the airfield, dangerous for the flight of aircraft. High buildings and constructions (towers, masts, plant chimneys and others) are marked by red obstruction lights, installed on the top outline of obstructions and along the vertical line of a construction.

Illuminated takeoff area is a spare system of light equipment in case of the failure of stationary equipment. The illuminated takeoff area can even be used in the organization of takeoffs (landings) of aircraft in the direction not provided for by the stationary landing aids. The light sources for the lights of the illuminated takeoff area are incandescent lamps with centralized or individual power supply.

For the prevention of the blinding effect of lights on the pilot's eyes the light power of the lighting equipment of airfields can be regulated depending on the degree of transmittance of the air.

The airfield lighting equipment is designed to facilitate landings (takeoffs) of aircraft on the RW from both directions. If when designing the takeoffs and landings are provided for always only from some one end of the strip, part of the light equipment, placed on the opposite end, becomes superfluous (approach lights, horizon lights).

## § 51. ELECTRONIC EQUIPMENT

The airport radio aids can be divided into the following basic systems:

aircraft instrument landing approach system by homing stations (OSP system);

aircraft instrument landing approach system by localizer glide-path beacons (SP-50 system);

radar systems for monitor and control of aircraft traffic; electronic short-range navigation systems.<sup>1</sup>

The OSP system is designed for guiding the aircraft to the area of the airfield, accomplishing the maneuver of landing course approach and descent along the landing course to the altitude at which a contact landing is accomplished. The contact landing can be realized using the signaling equipment system or by terrestrial reference points.

The equipment of the OSP system includes ground and airborne equipment. The ground equipment consists of two medium-wave homing stations, placed at 1100 and 4000 m from the beginning of the RW on the continuation of its axial line and two ultrashort-wave marker beacons placed together with the homing stations.

The SP-50 system provides the pilot information for the aircraft landing approach both along the course line and the glide path. The ground equipment of this system includes radio-range and glide-path beacons, and also the inner and outer marker beacons, which are used from the OSP system, since the OSP system usually supplements the SP-50 system.

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<sup>1</sup>Bromberg A. A., Grechishkin B. V., and others. Mechanical and Power-Generating Airport Equipment. Machine-Building, 1968.



The radar systems are intended for monitoring and controlling aircraft flights on routes, for detection and guidance of aircraft by instructions from the ground into the airport zone and zones of coverage of instrument systems OSP and SP-50, control of the correct descent of aircraft, and if necessary for guidance of this descent. The ground equipment of the radar system includes landing, airfield control and surveillance radars with course, glide-path and plan-position indicators, which are installed at control towers.

The electronic short-range navigation systems are intended for homing the aircraft into the airport zone with the provision for a subsequent maneuver for approach to the landing course, and also approach of the aircraft to radio navigation points outside the airfield. By radio navigation points we mark the entrances and exits of air corridors, the breakoff points of air routes. As the ground equipment of the electronic short-range navigation system we use medium-wave homing beacons, which enter the OSP system or are placed at radio navigation points outside the airport.

The OSP and SP-50 system, and also radar systems make it possible to calculate for "blind" aircraft landing approach, i.e., outside the visibility of ground and signaling equipment, but the final stage of landing, including touchdown and landing run on the RW, is performed visually. In the OSP system the main objects are the inner homing radio marker beacon and outer homing radio marker beacon, placed on the continuation of the RW axis from one or two directions of landing.

Control radio communication with aircraft, the monitoring of flights and control of them in the airport zone both during landing and takeoff are accomplished from the takeoff control points, usually combined with weather observation points, and also from the control tower. As an example Fig. 65 shows the

placement of the main objects of the OSP system from two directions of landing.

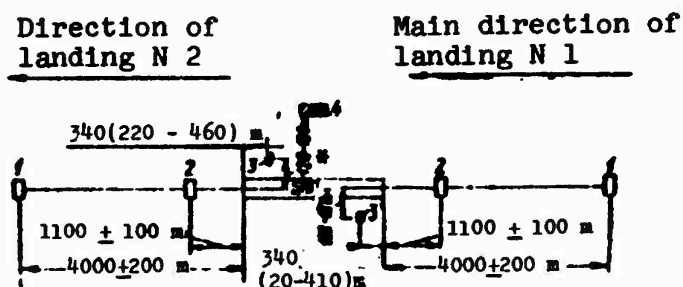


Fig. 65. The placement of main objects of the OSP system: 1 - outer marker beacon; 2 - inner marker beacon; 3 - takeoff control tower; 4 - control tower.  
\*120-[illegible] V

The OSP system provides the homing of aircraft into the airfield area from a distance of 150-200 km, their guidance and approach to the landing course.

The outer and inner homing marker beacons, included in the objects of outer and inner marker beacon points of the OSP system, are the medium-wave radio transmitting stations.

The operating conditions of their transmitting systems consists of continuous radio-wave emission with the intermittent feed of call signals of two letters of cable code for the outer marker beacon and one letter - for inner. The direction to the marker beacon is determined on aircraft by an automatic radio compass.

Inner and outer ultrashort-wave marker beacons are designed for signaling the flight past certain points. High-frequency oscillations, created by the marker beacon transmitter, are emitted by the antenna, which has a radiation pattern in the form of a vertical inverted cone, and the flight past radio beacons is signaled aboard the aircraft by a light and by a bell.

For maintaining the glide path the pilot considers the readings

of the radio altimeter established on the control panel and the distance to the touchdown points, determined by the signals of marker beacons.

In the SP-50 system the main objects are the radio-range beacon, glide-path beacon, inner and outer marker beacons. The radio-range beacon is placed on the continuation of the RW axis in the direction opposite the aircraft landing approach; the glide-path beacon is placed on the side of the RW axis behind its end on the side of the landing approach.

The inner and outer marker beacons are usually used from the OSP system. Control radio communication with aircraft, monitoring of flight and control of them are accomplished from the KDP and takeoff control points. An example of the placement of the main objects of the SP-50 system is shown in Fig. 66. Both glide-path beacons are located on the side of the unpaved takeoff area on the opposite side of the section of development and taxiways.

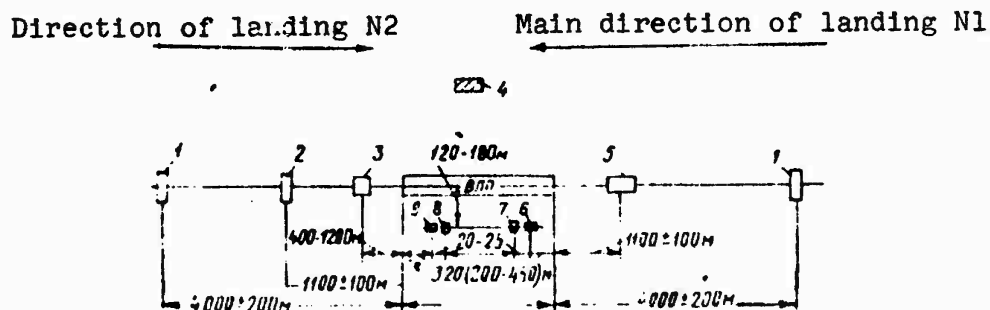


Fig. 66. Diagram of the placement of main objects of the SP-50 system: 1 - outer marker beacon; 2 - inner marker beacon; 3 - KRM-1 radio-range beacon; 4 - control tower; 5 - KRM-2 radio-range beacon, combined with inner marker beacon; 6 - GRM-1 glide-path beacon; 7 - SDP-1; 8 - SDP-2; 9 - GRM-2 glide-path beacon.

To provide landing from the main direction there are used the radio-range and glide-path beacons.

The SP-50 system supplies the pilot information for guidance of the aircraft to the RW on the course line and glide path from the boundaries of action of the system to the point where the course line intersects the glide path at a height of 60 m or below over the horizontal plane, passing through the near end of the RW (Fig. 67).

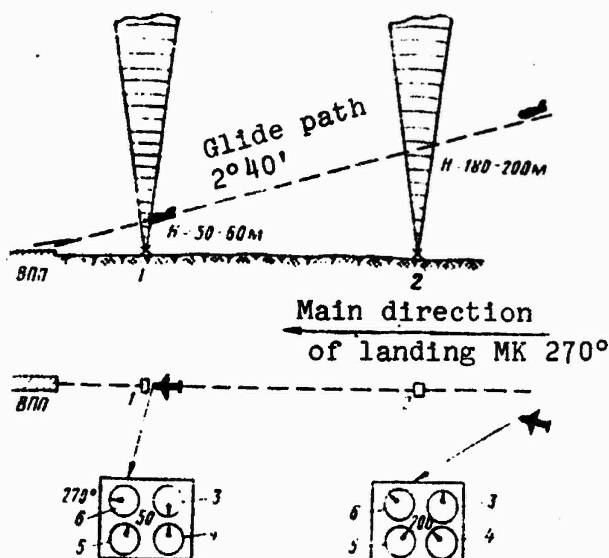


Fig. 67. Diagram of aircraft landing descent using the OSP system: 1 - radiation pattern of inner marker beacon; 2 - radiation pattern of outer marker beacon; 3 - automatic radio compass, tuned to the frequency of the outer homing station; 4 - automatic radio compass, tuned to the frequency of the inner homing station; 5 - radio altimeter; 6 - magnetic compass.

The main objects of the monitoring and control radar system are the radar stations, installed at points from which there is ensured the best field of vision of the space in the zone determined by the purpose of the station. Radars of the following purpose are used: surveillance for the control and monitoring of air traffic on long-range airport approaches; airfield control radar for the control and monitoring of air traffic in the area of airfields; landing for monitoring the descent of aircraft on the landing course and glide path and the control of landing by the issuing of instructions by the controller through the control radio station; radars for surveillance of the air field or monitoring the movement of aircraft, motor transport and special machines at night and with poor visibility in the daytime

on RW, taxiways and parking places of airfields; weather for determining the character and boundaries of cloud cover, position, shape, direction and speed of thunderstorms and heavy showers.

Furthermore, for determining the radio bearing of aircraft, and also for the individual identification of aircraft, discovered by surveillance and airfield control radar stations, ultrashort-wave automatic direction finders are used.

The KDP are intended for the central control of aircraft movement within the airspace in the area of the airfield (in the approach area and when making landing and takeoff), and also on the sections of air routes and local air lines, adjacent to the area of the airfield, and for monitoring the aircraft movement within the indicated limits.

Furthermore, at the KDP there are accomplished the control of movement of aircraft and special vehicles on the flying field, the planning and organization of every flight, the preflight preparation of the airplane crews, the drawing up of preflight and postflight documentation, the collection, processing and transmission of weather information, and also the remote control of electronic and signaling equipment of the airfield and the monitoring of their operation.

For communication between the services of the airport in the KDP there is provided a communications center, which consists of a radio office, combined, as a rule, with a receiving radio center, and a telegraph unit, and sometimes there is a built-in automatic telephone exchange.

The orders of the KDP are determined by the volume and intensity of the air traffic, control of which is accomplished from a given KDP; by the types of aircraft, whose flights are controlled

and checked; by the quantity of air lines (main and local) coming from a given airport; by the presence at the airport of a district control room and by the quantity of control directions in it; by the electronic and signaling equipment, with which the given airport is equipped; by the volume of operations of the communications center.

The intensity of air traffic at airports is various. The most intense is the traffic at airports of the I, II classes and at some airports of the III class. At airports of the IV class, especially V class, light aircraft mainly with piston engines are predominant.

When determining the order of the KDP one should also consider the work load of the traffic services with respect to the monitoring of aircraft flying through their zones. Taking into account that expounded above, KDP of the following orders have been established:

KDP-I and KDP-II - for airports with high traffic volume of aircraft with gas-turbine engines in the airport control zone, which have developed traffic services, a district control point and a large volume of operation of the communications center. As a rule, KDP-I and KDP-II are created at airports of the I and II classes;

KDP-III - for airports with medium traffic volume of aircraft with gas-turbine and piston engines and the presence at the airports of traffic services of district control point up to two-three directions; KDP-III, as a rule, are created at airports of the III and partially the IV classes;

KDP-IV - for airports with low traffic volume of aircraft with gas-turbine engines; KDP-IV, as a rule, are created at airports of the IV and partially the V classes. KDP-IV can be

recommended for the base airports of the detachments of local air lines;

KDP-V and KDP-VI - for airports of the V class, and also for unclassified airfields of local air lines. These KDP are designed for the placement in them of a simplified set of radio equipment, communication facilities and one controller.

In the KDP of all orders there are provided services and control room channels of aviation air and ground radio and line communication, and also control room automatic sound recording and reproduction (tape recording) of the conversations of the controllers on the communication channels. The higher the intensity and volume of air traffic, the greater the extent to which there is provided the separation of functions of the controllers with corresponding increase in operators positions and channels of aviation air and ground communications. This entirely relates to services that provide the preflight preparation of crews and the drawing up of preflight and postflight documentation.

KDP-I and KDP-II are designed in the form of separate buildings, which are located at a distance of not less than 100 m from the air terminals. KDP-III can be placed at a distance not less than 50 m from the air terminal. KDP-IV are sometimes interconnected with buildings of typical air terminals with 100 or 200 people, KDP-V and KDP-VI - single-story buildings, combined with an air terminal or passenger service building of 30 and 100 passengers. For all orders of KDP there is provided a light tower for visual surveillance of the air approaches of the flying field and ramp. This should be taken into account when selecting the place of construction of the KDP.

As the radio equipment of short-range navigation with the use

of the radio compass installed aboard the aircraft medium-wave homing beacons are widely used, which enter the outer marker beacon of the OSP system, which was examined above. The homing beacons can be installed outside the airfield. In this case they provide the guidance of aircraft to a certain radio navigation point outside the airfield and the marking of the moment of flight past the point (the entry and exit of the corridors of air zones, breakoff points of air routes).

As the electronic systems of short-range navigation there are also used omnidirectional ultrashort-wave azimuth and range-finding beacons, which provide upon request the continuous transmission of information to the aircraft for determining the current values of azimuth and slant range of aircraft and thereby determining its location or the guidance of the aircraft to a certain point in the area of the airfield or outside it.



## CHAPTER XIII

### ACCESS HIGHWAYS

#### § 52. PURPOSE

During the building of an airfield on highways there are transported building materials, machines and equipment necessary for accomplishing the construction work. Before setting up the basic construction works it is advantageous to construct highways directly at the airfield.

Access highways with respect to purpose are subdivided into main and secondary.

The main highways connect the airfield site with roads of the total network of state or local importance, serving for communication with the city. Secondary roads are intended for the organization of the main traffic on the territory of the airport and for the access of automobiles to buildings and constructions (base fuel depots, habitable settlements, communications and radio navigation installations).

The main highways most frequently join perpendicular to the area near the terminal and the main facade of the air terminal (Fig. 68a). Sometimes the main road approaches parallel to the area near the terminal (Fig. 68b). The form of joining is selected

taking into account the characteristics of the airport, consideration of the features of the territory of the airport and special technical and economical calculations.

Access highways depending on the class of airport pertain to the following categories (according to the classification of All-Union roads):

a) main access roads at airports of the I class - to the I category; at airports of the II and III classes - to the II category; at airports of the IV and V classes - to the III category;

b) secondary access highways at airports of all classes - to the III category.

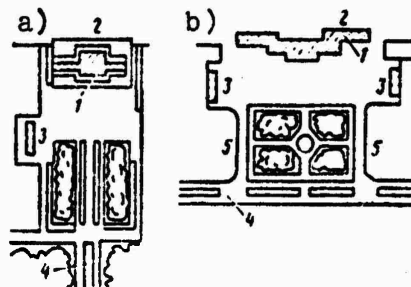


Fig. 68. Diagrams of joining of access roads to the airport: a) perpendicular joining; b) parallel joining. 1 - air terminal; 2 - ramp; 3 - automobile station; 4 - access highway; 5 - automobile parking area.

The basic parameters of access highways are taken in accordance with their category (Table 59).

Table 59.

Parameters	Category of the main road			Category of secondary road
	I	II	III	III
Number of lanes	4	2	2	1
Width of lanes, m	3.75	3.75	3.50	-
Width of travelling part, m	15.0	7.5	7.0	3.5-5.0
Width of verge (with the absence of curbs), m	3.75	3.75	2.50	2.50
Dividing strip	1	-	-	-

Secondary access highways to radio objects, located outside the airport, regardless of the class of airport are taken, as a rule, with width of the part suitable for vehicles 3 m. The main access highways, as a rule, are constructed with improved capital types of coverings (cement-concrete, asphalt, from dense crushed stone materials, treated with viscous bitumen or tar).

On the secondary access highways are constructed coverings of improved and simplified types (crushed stone from soil processed in an installation with viscous bitumen, from cold asphalt).

The stretch of the network of highways to the airport should be minimum. Therefore it is advantageous to select the section for the building of the airport near the existing state and local highways. Access highways should satisfy the requirements of TU and norms for the planning and building of highways.

#### § 53. CROSS SECTIONS

The cross section is the section of the highway with vertical plane perpendicular to its axis. Depending on the terrain features the cross section of the highway is in an embankment or in a ditch (Fig. 69). The basic element of the cross section of the highway is an earth road bed. The earth road bed provides the stability of the travelled part and smooths the roughness of the relief.

Embankments with height up to 1.5 m are built from the soil of side ditches, reserves or cuts. Embankments with height from 1.5 to 12 m are built from the soil of reserves. Low embankments are the most stable, therefore it is advantageous to construct them on access roads and roads inside the airport. The cross section of the earth road bed in cuts should be such that the earth road bed would be little piled up.

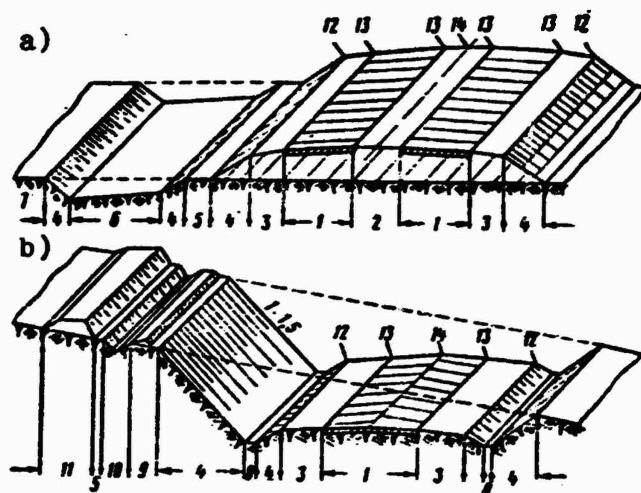


Fig. 69. Cross sections of highways: a) in an embankment; b) in a ditch; 1 - travelled part; 2 - dividing strip; 3 - verge; 4 - slopes; 5 - berm; 6 - bottom of reserve; 7 - border of branch strip; 8 - bottom of ditch; 9 - banquette; 10 - banquette ditch; 11 - earth bank; 12 - edge of dirt road bed; 13 - edges of travelled part; 14 - axis of road.

On the surface of the earth road bed we construct the road surface with the travelled part intended for the movement of motor transport. The top layer of the road surface, directly receiving the effect of the wheels of automobiles, is called the surface.

With two-way motion the travelled part of the road is divided by a dividing strip.

The dirt strips adjacent to the road surface are called verges. The verges are constructed with width from 2.5 to 3.75 m and are used for the temporary stopping of automobiles, materials and road machines are also placed on them during repair works on the roads. For the draining of water along the earth road bed are constructed side trenches-ditches. The shelf between the embankment and the reserve is called the berm. With the construction of earth road bed in the cut the soil being removed is used for the mound of the embankment or is taken away beyond the cuts into earth banks.

The side surfaces of embankments and cuts are called slopes. The steepness of the slopes is designated so as to provide stability of the soil. The steepness of slopes depends upon the quality of soils, height of embankments (Table 60) or the depth of cuts (Table 61).

Table 60.

Soil of embankment	Height of embankment, m	Steepness of slopes
Stone from slightly weathered rocks	Up to 6	1:1-1:1.3
Coarse and medium size of sand, gravel, pebbles, crushed stone and rotten stone soils of slightly weathered rocks	" 12	1:1.3-1:1.5
Other soils, suitable for the erection of embankment	" 12	1:1.5
	" 6	1:1.5
	" 12	In the upper part up to 6 m 1:1.5; in the lower - 1:1.75

Table 61.

Soil of cut	Depth of cut, m	Steepness of slopes
Clays, loams, sands, sandy loams of uniform composition	Up to 12	1:1.5
Loess under conditions of arid climate	" 12	1:0.1-1:0.5
Loess under other conditions, and also loess-type soils	" 12	1:0.5-1:1.5
Coarsely thrashed (rubble, gravel and others) soils depending on the stratification	" 12	1:1-1:1.5
Slightly weathered rocks with the absence of fissured state and slope of stratum toward the road bed	" 12	1:0.2
Other rocks	" 12	1:0.2-1:1.5

For the draining of water the surface of the travelled part is constructed with a cross fall from the axis of the road to the

shoulders of the earth road bed. The cross fall is characterized by the ratio of the difference of marks of the end points of straight sections to the distance between them and is shown by a decimal or in thousandths ( $\text{‰}$ ). The cross falls should not impair the conditions of motion of automobiles over the covering, therefore their values are standardized (Table 62).

Table 62.

Covering	Cross falls, $\text{‰}$	
	smallest	greatest
Cement-concrete and asphalt-concrete	15	20
From crushed stone, gravel and other materials, treated with organic binding agent	20	25
Crushed stone and gravel	25	30
Soil, reinforced with local materials	30	40

The verges are given a cross fall greater than the slope of the travelled part usually by 20 $\text{‰}$ .

The contours of the surface of the road covering of the travelled part are taken convex in the form of two inclined straight lines, conjugated by a circular curve (Fig. 70).

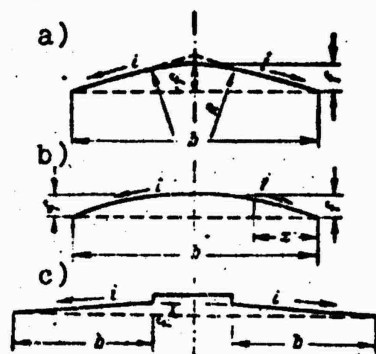


Fig. 70. The cross sections of the surface of the road covering: a) on inclined straight line, conjugated with curve; b) on parabolic curve; c) with a dividing strip.

The radius of curvature of the middle part is determined by formula

$$R = \frac{b}{\alpha}. \quad (72)$$

The convexity is determined by formula

$$f = \frac{1}{2}(b-1)l, \quad (73)$$

where  $b$  - the width of the travelled part, m;

$l$  - slope of travelled part, ‰.

With two-way motion on the highways with dividing strip each half of the travelled part is constructed with single-slope profile, and the rise in this case is determined by formula

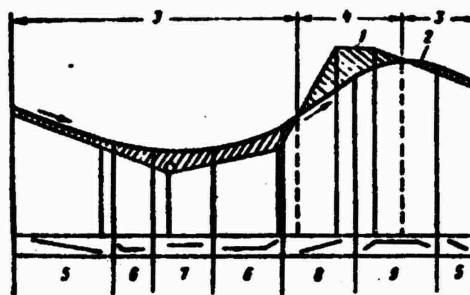
$$f = bl. \quad (74)$$

The construction of the travelled part with two-slope profile on each half is allowed when it is possible to accomplish draining from the dividing strip. The dividing strip is constructed single-slope with slope to the axis or from the axis of the road.

#### § 54. LONGITUDINAL SECTION

The longitudinal section is the section of the highway with the vertical plane passing through its axis. On the longitudinal section there is plotted the surface line of the soil along the axis of the road and the project line of the highway (Fig. 71). The surface line of soil is plotted along the axis of the road as a result of levelling of the route. The project line is traced along the project marks and corresponds to the longitudinal section along the edge of the earth road bed. The project line consists of convex or concave curves, which ensure the smooth passage of the automobile from the sections of the road which

Fig. 71. Longitudinal section of the road: 1 - surface line of soil; 2 - project line; 3 - embankment; 4 - cut; 5 - slope; 6 - concave curve; 7 - horizontal area; 8 - rise; 9 - convex curve.



have various longitudinal fall. The project line can pass above and below the surface line of soil. In the first case the earth road bed is constructed in an embankment; in the second case the earth road bed is constructed in a cut. The height of embankment or the depth of the cut is determined by the difference of marks of the project line and marks of the surface line of soil. At the points of intersection of the project line and the surface line of soil the difference of marks is equal to zero, and the points of intersection are called zero.

The project line should provide the smooth and safe motion of automobiles at high speed with minimum expenditures for the building and operation of roads. These requirements are accomplished by observance of the established norms in the relationship of longitudinal falls of roads, discontinuities of longitudinal section and vertical curves.

The best conditions for the motion of automobiles will be when the longitudinal falls of roads will be maximally slanting (not more than 30%). The observance of these requirements is not always possible, since the longitudinal falls depend upon many factors, including the terrain features, the type of automobile, running speed and others. With respect to construction norms the greatest longitudinal falls can be increased to 50-60%, sometimes to 70 to 100%. The horizontal position of the project line is allowed with the provision of drainage: in cuts the project line should have slope not less than 5% for the drainoff of surface water.

Certain requirements are imposed on the discontinuities of the longitudinal section. Upon transition from one slope to another



there are observed impacts of the automobile wheels against the surface, leading to the overloading of springs, inadmissible vibration, deterioration of visibility. For smooth automobile motion it is advantageous to construct straight sections with the greatest possible length with uniform slopes. In this case for standard conditions of automobile motion with longitudinal falls more than 60‰, on separate sections we smooth the longitudinal fall up to 20‰.

The minimum distances between discontinuities are designated depending on the running speed of automobiles and the conditions of inscription of vertical curves (convex or concave) on the project line of the road. In this case the difference of slopes of adjacent sections should be not less than 5-10‰.

Vertical curves are most frequently broken up in the form of circular curves. The radii of vertical curves should be as large as possible for smoother joining and the best visibility.

The construction norms for the designing of highways (SNiP II-D.5-62) recommend designating the radii of convex vertical curves 60,000 m, and concave 8000 m. If according to the conditions of the relief it is not possible to accomplish such large radii, they are taken smaller (Table 63).

Table 63.

Speed, km/h	Smallest radius		Speed, km/h	Smallest radius	
	convex ver- tical curves, m	concave ver- tical curves m		convex ver- tical curves, m	concave ver- tical curves, m
150	25,000	8,000	60	2,500	1,500
120	15,000	5,000	50	1,500	1,200
100	10,000	3,000	40	1,000	1,000
80	5,000	2,000	30	500	600

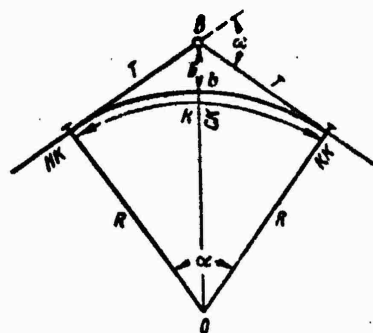
On the longitudinal section we place all the constructions set up on the highways. For the greatest clarity the horizontal scale of the longitudinal sections is 1:5000, and vertical - 1:500. The longitudinal section, made up in the established form, contains all the basic data necessary for building the highway.

## § 55. LAYOUT OF THE ROAD

The route is the geographic representation of the axis of the road on the horizontal plane. The route must be laid out in the shortest direction. As a result of obstructions (lakes, bogs, ravines, etc.) when packing the road it is necessary to select the most convenient places in bypassing the available obstructions. Therefore the layout of the route is usually a meandering line composed of separate straight sections, joined by curves.

The main geometric elements, which characterize curves, are: angle of rotation  $\alpha$ , radius  $R$ , curve  $K$ , tangent  $T$ ; bisector  $\bar{b}$  (Fig. 72).

Fig. 72. Geometric elements of curves:  
HK - point of curvature;  
CK - middle of the curve; KK - end of the curve;  $\bar{b}$  - bisector;  
T - tangent; R - radius;  
K - curve; B - apex of the angle;  $\alpha$  - angle of rotation.



The tangent is equal to the distance along the tangent from the beginning or end of the curve to the apex of the angle and is determined by formula

$$T = R \operatorname{tg} \frac{\alpha}{2}. \quad (75)$$

The length of the curve is determined by formula

$$K = \frac{\pi R \alpha}{180} \quad (76)$$

The distance from the apex of the angle to the middle of the curve is called the bisector and is determined by formula

$$B = R \left( \sec \frac{\alpha}{2} - 1 \right) = R \frac{1 - \cos \frac{\alpha}{2}}{\cos \frac{\alpha}{2}} \quad (77)$$

The difference between the sum of two tangents and the length of curve is called the final measurement and is determined by the following expression:

$$A = 2T - K \quad (78)$$

For the safe motion of automobiles at top speed the radii of curves in the plan are recommended not less than 3000 m. Sometimes with considerable increase in the volumes of works and accordingly the cost the construction norms and regulations (NiP II-D. 5-62) allow a decrease of the radius of curves in the plane to 1000 m, and for the difficult sections of intersected and mountain terrain sometimes even less.

On the curves with radius up to 1500 m we construct connection curves with gradually decreasing radius from infinity (on a straight line) to the radius of a circular curve. Depending on the conditions of laying out the route on the terrain there can be various joinings of curves: two straight lines by curves of one radius (Fig. 73a); two adjacent curves of different radii (Fig. 73b); one-sided curves with straight inset (Fig. 73c); reverse curves with straight inset (Fig. 73d) and reverse curves (Fig. 73e).

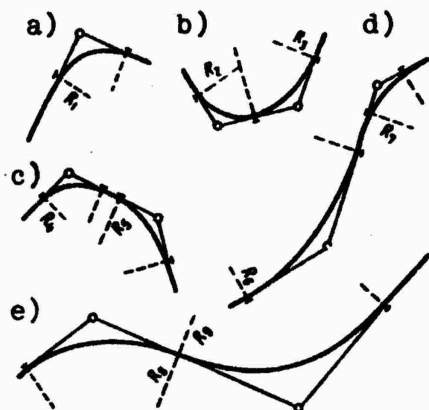


Fig. 73. Forms of joining of curves.

In order not to allow large longitudinal falls on the sections of roads in mountain terrain, the route is laid out along the slope so that due to an increase in the length of the road the slope would not exceed the maximum permissible. In such cases large turning slopes are allowed with restriction of the calculated running speeds of automobiles to 15-30 km/h. The curves in this case are inscribed outside an angle. Such curvature is called a hairpin bend.

The layout of the route is plotted for plain terrain to scale 1:10,000, and for mountain 1:5000. The route in the plan (Fig. 74) is broken down into kilometers and stakes (one stake is equal to 100 m).

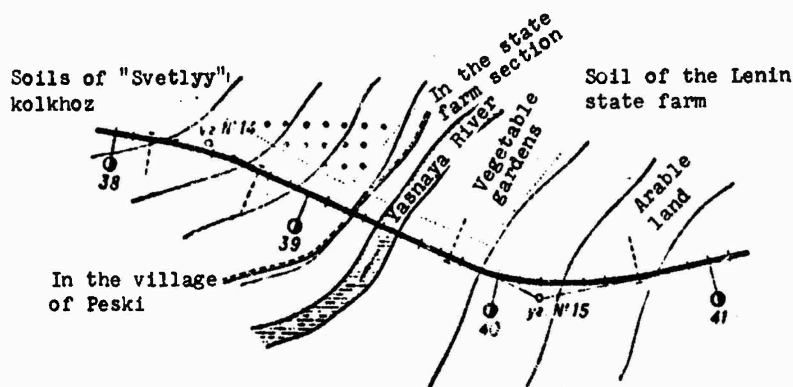


Fig. 74. Layout of road.  
[γ: = Angle].

On the layout are also indicated the numbers of angles, points and the lengths of straight lines. On each side of the route to a width of 0.6 m on the layout symbols show the situation: basins, populated areas, communication lines, features of terrain, position of reference points. When designing the layout it is necessary to provide measures facilitating safety of motion. On curves with radius 700 m and less it is necessary to widen the travelled part 0.5-2.0 m on the inside of the curves because of verges; in this case the width of the verge is left not less than 1 m and 0.5 m in mountain terrain.

Visibility in the plan should be such that the driver could notice an obstruction and have time to stop. The distance of the calculated visibility is taken not less than 75-100 m. To provide visibility on curves the space on the inside of curvatures should be free of obstructions (slopes, cuts, vegetation, buildings, etc.).

#### § 56. CONSTRUCTION OF THE ROAD SURFACE

The road surface absorbs loads from moving automobiles and transfers them to the ground. The construction should possess sufficient strength, evenness, dustlessness and have a rough surface, which creates reliable cohesion of automobile wheels with the surface of the covering. The road surface consists of a number of structural layers (Fig. 75). The top layer of the road surface (covering) can be rigid and nonrigid.

Rigid structures can absorb considerable bending stresses and work as plates on elastic supports. Such constructions include cement-concrete and reinforced concrete coverings. Nonrigid constructions possess insignificant resistance to bending stresses and their strength is determined mainly by the strength of the base. Nonrigid type constructions include: black, crushed stone

and gravel asphalt-concrete coverings, constructed by the impregnation method or mixing on the road, coverings of soils reinforced by binding agent. The selection of constructions of the road surface depends upon the purpose of highways, soil and hydrological conditions, the presence and properties of local building materials.

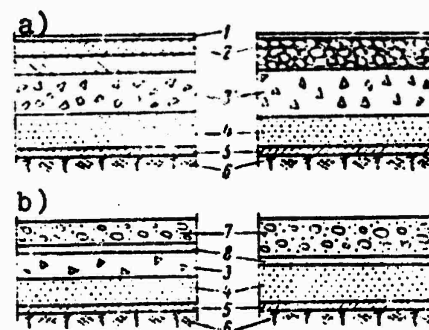
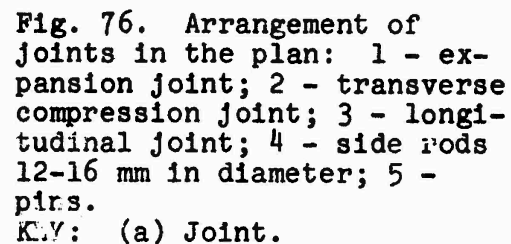
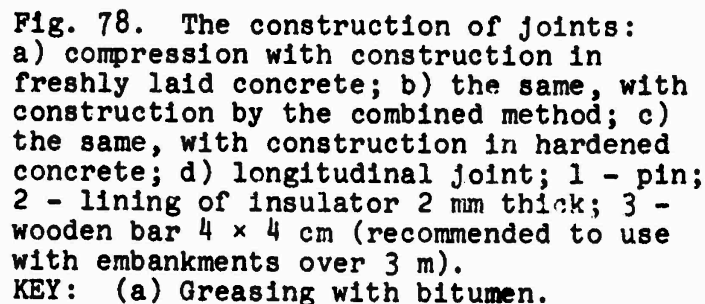


Fig. 75. Constructions of road surface: a) nonrigid type; b) rigid type; 1 - protective layer; 2 - covering (two-layered or single-layer); 3 - base; 4 - additional layer of base; 5 - anti-mud filling layer; 6 - soil road bed; 7 - concrete covering; 8 - intermediate layer.

Cement-concrete coverings have high bearing capacity, which does not depend upon the season of the year and condition of the soil, low wear, comparatively low maintenance costs and make it possible to mechanize their construction and use the production-line method. Cement-concrete coverings allow high traffic volume - more than 6000 automobiles per day. For the prevention of cracking from internal temperatures and shrinkage stresses the cement-concrete coverings, just as the coverings of airfields, are broken down into separate slabs with longitudinal and transverse seams (Fig. 76). The longitudinal seam is constructed according to the type of compression joint. The distance between the transverse compression joints and expansion joints are taken according to the project depending on the climate conditions of the area of building. For the strengthening of the edge and corner sections of rectangular slabs we construct pin connections, which transfer part of the load of one slab to another and allow longitudinal movement of slabs, caused by temperature factors. In the expansion joints (Fig. 77) the pins are installed every 0.30 m. The distance between pins in transverse and longitudinal joints (Fig. 78) is 1.0 m. With the construction of coverings on



Technical drawing of a mechanical part, likely a bracket or support, showing dimensions and labels. The drawing includes a side view on the left and a top view on the right. The side view shows a vertical section with a total height of 100 (50+50) and a width of 100 (50+50). The top view shows a rectangular base with a central slot. Dimensions for the top view include a total width of 100 (50+50) and a central slot width of 20. Labels 1, 2, 3, and 4 point to specific features: 1 is the central vertical post, 2 is the top horizontal surface, 3 is the right vertical surface, and 4 is the top horizontal surface of the central slot.



sand bases the longitudinal edges of the slabs are reinforced by the packing of corrugated reinforcing rods with diameter 12 mm into the concrete. The rods are placed 5 cm higher than the bottom of the slab. For decreasing the quantity of transverse compression joints we construct reinforced concrete coverings, which are reinforced along the entire width. The reinforcement iron strengthens the top layer and prevents the opening of cracks, caused by moving loads and by temperature fluctuations. The reinforcement of slabs is accomplished in the top layer by a network of corrugated rods of class A-II 12-14 mm in diameter with mesh  $20 \times 25$  cm. The expansion joints in reinforced concrete coverings are placed every 25-50 m. The construction of transverse expansion joints in reinforced concrete coverings is accomplished just as for cement-concrete coverings. Cement-concrete and reinforced concrete coverings are constructed 18-22 cm thick.

To provide movement of slabs on the base under the action of a change in the temperature and the elimination of freezing of the underlying layer with concrete between slabs and the base there is placed bituminized paper or sheets of plastic, if the covering is constructed on a sand base or ordinary sand has been applied as a sublayer. Besides cast in-situ cement-concrete coverings, precast coverings are constructed. On Fig. 79 there are given unreinforced concrete slabs  $1 \times 1.0$  m and  $1.5 \times 1.15$  m in size. In the corner of the butting of four slabs there are laid two reinforcing rods, the seam is filled in with cement mortar. The slabs are placed with a 3-ton crane. Precast prestressed slabs 1.75-3.0 m wide and 6 m long are constructed according to the type of prestressed airport slabs.

It should be noted that as yet sufficiently economic constructions of road slabs for precast cement-concrete coverings have not been developed. Asphalt-concrete coverings are constructed with traffic volume 6000 automobiles per day and above; gravel and crushed stone coverings, reinforced with binding



agent in an installation, are constructed with traffic volume from 3000 to 6000 automobiles per day; roads of soils, improved by granulometric additions, and also reinforced with mineral materials, are used with traffic volume from 200 to 3000 automobiles per day. The bases of road coverings are constructed from grained materials, from soils reinforced with binding agents, from lean concrete.

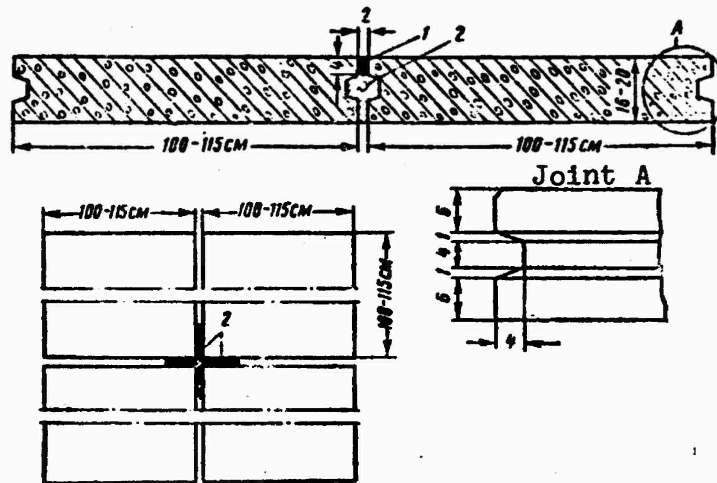


Fig. 79. Slab used during the construction of the precast covering on the Kiev-Odessa Road.

Depending on the type of covering, soil and hydrological conditions, the presence of local materials, the bases are constructed in one or several layers. The top layer of the base, receiving the effect of static and dynamic transport loads, is constructed from durable materials, for the bottom layers less durable materials are used.

#### § 57. DRAIN

The stability and the strength of the earth road bed and road surface are provided only with sufficiently high bearing capacity of soil, which is determined mainly by its moisture. With the

overmoistening of soils the bearing capacity is highly lowered, which leads to a reduction in the strength and stability of the earth road bed and road surface.

The sources of the moistening of earth road bed can be atmospheric precipitation, water which drains from the ground catchments adjacent to roads and which stood too long near the road bed, and also ground water. For combatting overmoisturing of soil there is provided a drain system, which includes constructions for the collection, holding and drain of water from the earth road bed.

For the collection and removal of surface water in cuts and at embankments with height up to 0.6 m side trenches (ditches) are constructed. With the presence of reserves (Fig. 80) they are used as drain constructions. The ditches are of trapezoidal and triangular shape. The trapezoidal ditches are constructed in a locality with intense precipitation, high level of ground water and with poorly draining soils. The triangular profile of

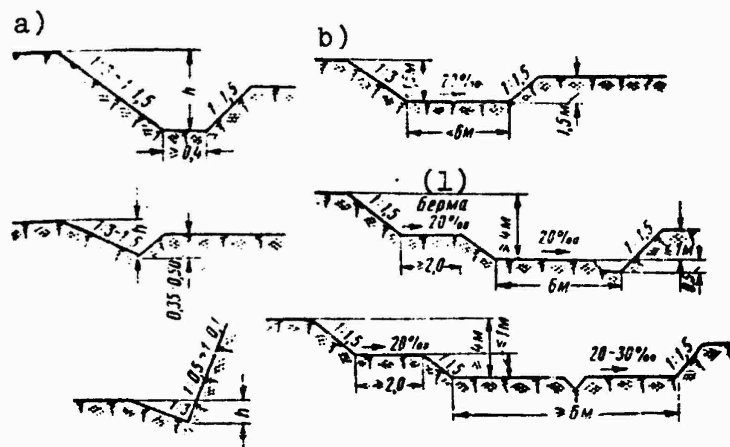


Fig. 80. Cross sections: a) ditches; b) reserves.  
KEY: (1) Berm.

ditches is designated for embankments in a locality with insignificant precipitation, in well draining soils and low level of ground water.

The runoff of water from trapezoidal ditches and reserves is accomplished every 500 m; from triangular ditches - every 150-200 m.

The runoff of water from ditches into low places is accomplished by drainage ditches, which are of trapezoidal shape with minimum depth 0.5 m and width along the bottom 0.4 m. So that they would not be overfilled, the length of the drainage ditches is designated not more than 500 m; the slope is taken not less than 7‰. For the catching and draining of water, which runs off to the road on an incline, we construct high ditches with trapezoidal cross sections. It is not recommended to make the depth of the high ditch and width along the bottom less than 0.5 m, the slope is taken not less than 30-50‰. If on separate sections draining is difficult, and at a depth of 3-5 m lie permeable soils (coarse sand, pebbles, gravel, cracked limestone), we construct water-absorbing wells. They let through the surface water from the side ditches into the underlying permeable soils.

For the catching and removal of ground water we construct drainages, which lower the level of ground water. In the majority of cases closed drainage ditches are created (Fig. 81). Their depth is made lower than the depth of freezing and 0.3-0.5 m lower than the water-bearing layer; the width along the bottom is designated from 0.3-0.5 to 0.7-1.0 m (with depth more than 1.25 m). Along the bottom of the ditch are laid pipe drains with holes or slots for the entry of ground water. Above the pipes are placed filtering layers, which are packed with dense clay soil, which does not allow the penetration of surface water into the ditch. The drainages are laid along the road under ditches or near them. The longitudinal fall of the bottom of the drainage

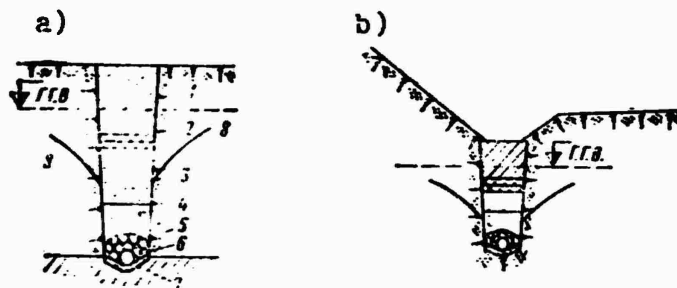


Fig. 81. Diagram of closed drainage: a) ordinary; b) under a ditch; 1 - packed clay soil; 2 - two layers of sod with roots down; 3 - coarse-grained or medium-grained sand; 4 - crushed stone or gravel; 5 - crushed stone or gravel 40-70 mm in size; 6 - drain pipe; 7 - crushed stone, tamped into the soil; 8 - depression curve.

ditches is 5-7%. Water collected by the drainage is drained off toward the low places. For decrease of the penetration of capillary water into the earth road bed besides drain devices it is necessary to pack the soil of the earth road bed well, raise the edge of the earth road bed above the ground-water level, and sometimes construct the road bed from soils which possess low height of capillary rise. The types of reinforcements of the ditches of the construction of outlets of the other elements of the sewer and drainage network are similar to the constructions of the drain network of airfields examined above.

## CHAPTER XIV

### ACCESS RAILWAY LINES

#### § 58. PURPOSE

Railroad siding tracks during the building period are used for the transporting of building materials and equipment, and during the period of operation of the airport they are intended for the delivery of technical equipment, fuel, lubricants. In a number of cases, particularly at airports of the I class with large volumes of passenger transportation, the siding tracks are used for the delivery of passengers from the city to the airport and back.

Railroad siding tracks are provided, as a rule, only at airports of the I, II and III classes. At airports of the IV class such tracks are constructed only when materials which enter mainly by railroad are used for building the airport. The advisability of the building of access railway lines is determined by the technical and economical substantiation.

The joining of siding tracks to the railroads of the Ministry of Railroads is accomplished, as a rule, at district and through stations. The joining of siding tracks to large and complex junctions is not recommended. In the case of the access of siding track to such junctions the joining is allowed upon agreement with the departments of the Ministry of Railroads.

The railroad siding track should provide for the movement of locomotives and rolling stock, being in conversion to railroad networks of the Ministry of Railroads. It is planned as applied to railroad lines of the III category.

The main requirements for railroads of the III category are the following: net freight traffic in each direction for the fifth year of operation not more than 2-3 million t-km/km; rate of growth of freight traffic not more than 200 thousand t-km/km per year; passenger movement not more than three pairs of trains per day. These indices can be refined in each particular case proceeding from local conditions and by agreement with the departments of the Ministry of Railroads.

#### § 59. THE MAIN ELEMENTS OF RAILROAD SIDING TRACKS

The main elements of railroad siding tracks are: railway line with substructure and superstructure; separate points which include stations and sidings; constructions for alighting, debarkation and catering of passengers; official buildings; constructions for storage, loading and unloading of cargo; artificial constructions (bridges, tubes, tunnels); power supply devices; devices of signalization, centralization and block system (STsB) and communications. Depending on the work volume of siding tracks, topographic conditions, the class of airport the technical equipment of railroad lines can be various. Siding tracks are constructed under electric or diesel traction, single-track with wide gauge. The width of the standard gauge of the roads of the USSR on straight sections has been established at 1524 mm with tolerances for newly constructed lines +6 and -3 mm. Along the railway lines to the airport there are placed railroad depots, loading platforms and areas for the reception of large and little value cargo. The area of railroad depots should allow the simultaneous unloading of not less than 5-10 cars (depending on

the class of the airport). At the railroad siding track there is also placed the area of reception of all types of aircraft fuel. The area includes overflow pipes, pump works and reservoirs. When the access railway line is intended for the transportation of passengers, on the sidings there should be provided locations and devices for the catering of passengers (passenger platforms, passenger buildings and booking offices).

The sidings should have official places for maintenance personnel and direct telephone communication with the joining station. The earth road bed, superstructure, artificial constructions and various devices are designed on the basis of "Standards of designing railroads with 1524 mm gauge of the total network" (SNiP II-D. 1-62).

#### § 60. LONGITUDINAL SECTION AND LAYOUT OF THE ROUTE

The route is the longitudinal axis of the railway line at the level of the edge of the main area of the earth road bed.

The longitudinal section of the railroad is the vertical section along the longitudinal axis, expanded to the plane.

As the layout of the road there is the projection of the route to the horizontal plane.

The safety of movement of trains, the normal operating conditions of the railway line, and also the provision for reduction in the cost of building and operation require that the longitudinal section and the layout of the route satisfy certain specifications. The longitudinal section is characterized by the length of its elements, amount of slopes, conditions of joining of separate elements. By the length of elements we mean the distance between the points of discontinuity of the profile, where the steepness

of the slope is changed. By taking short lengths of elements, it is possible to attain the maximum approach of the project line of the profile to the ground surface and thereby considerably decrease the volumes of works on the construction of embankments and cuts and accordingly decrease the cost of construction. However the use of elements of such length complicates operation, since the frequent discontinuities of longitudinal section appearing with this cause additional forces in the couplers of the train. This disturbs the safety and smoothness of motion. Therefore the longitudinal section of the line is designed so that the length of its separate elements as a rule would not be less than the calculated length of the train  $l_{\text{эл}} \geq l_{\text{п}}$  (Fig. 82a), so that under the train there would not be more than one discontinuity of the road profile. When difficult terrain conditions exist there is allowed decrease of the length of element up to half the length of the train  $l_{\text{эл}} \geq 0.5l_{\text{п}}$  (Fig. 82b). The slope steepness of the element of the longitudinal section is defined as the ratio of the difference of marks of adjacent points in meters to the distance between these points in kilometers (%).

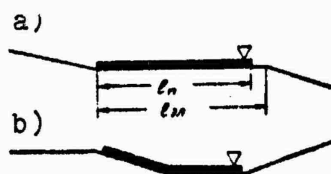


Fig. 82. Location of a train with different length of elements of the profile:  $l_{\text{эл}}$  - length of element of profile;  $l_{\text{п}}$  - length of train; a)  $l_{\text{эл}} > l_{\text{п}}$ ; b)  $l_{\text{эл}} = 0.5l_{\text{п}}$

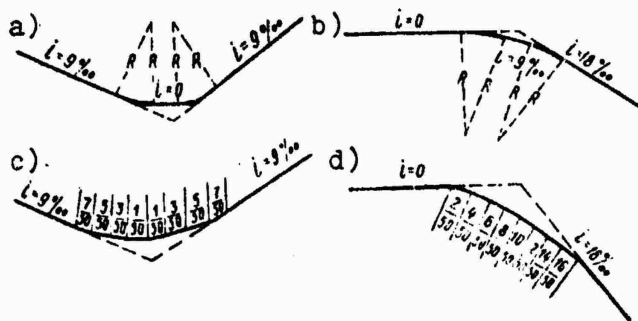


Fig. 83. The joining of abutting elements: a) when a dividing area exists; b) with elements of transfer curvature; c and d) profile of curvilinear contour.



The slope, which determines the greatest steepness of elements of the longitudinal section, is the ruling gradient - the calculated rise, by the magnitude of which in traction calculations there is established the weight of the freight train. The magnitude of the ruling gradient is selected on the basis of technical and economical calculations, topographic conditions of the locality and the gradients of adjoining railroads. With ruling gradient up to 4‰ there are ensured standard conditions of pulling of the train. The maximum value of the ruling gradient is determined by the topographic conditions of the locality and by the creation of favorable braking conditions during the motion of a train on grades. According to standards the ruling gradient on the railroad lines of III category should not exceed 20‰.

The smoothness and the safety of motion much depend upon the conditions of the coupling of the separation elements of the longitudinal section. With a large difference in the gradients of abutting elements there are observed overloads of the separate axles of rolling stock, a sharp change of tractive forces in the couplers, which is inadmissible with respect to the operating conditions of rolling stock. For the elimination of these phenomena with a large difference in the slope steepness of abutting elements (on lines of the III category with algebraic difference of gradients more than 8-14‰ - depending on the calculated length of the train) between the abutting elements of the profile there are designed dividing areas (Fig. 83a) or elements of the transfer curvature (Fig. 83b) with length not less than 200-350 m (depending on the calculated length of the train). In this case the transition of one gradient to another (with difference of gradients more than 3‰) is accomplished in the vertical plane of a curve, whose radius for the railroads of III category has been established at 5000 m.

Another method of the joining of abutting elements of the profile - the designing of short elements of gradually changing

curvature (Fig. 83c), with the aid of which there is accomplished the smooth transition from one gradient to another (so-called curvilinear profile). The length of such short elements, as a rule, is not less than 50 m, and sometimes - not less than 25 m (length of rail). The algebraic difference of the gradients of abutting elements for railroads of III category should be not more than 2‰.

The layout of the route of the railroad is a different combination of straight lines connected together by curves. To ensure the smoothness of motion of the train and decrease of disorders of the line the regulations for the technical operation of railroads impose certain requirements on the magnitude of the radius of curves. With curves with radius less than 1000-1200 m there is observed increased wear of the wheel tread bands of rolling stock, disorder of the undercarriage of locomotives and cars from lateral forces. Curves of large radii prove to be too long, which impairs the operational maintenance of the line.

Hence as a rational value one should consider the radii of curves not more than 4000 m and not less than 1200 m. On lines of the III category for reducing the volume of ground works there is also allowed the use of radii of smaller values (up to 600 m). Under difficult conditions with corresponding technical and economical substantiation for railway lines of the III category there are allowed curves with radius up to 350 m. Straight and curved sections of the line are mated by means of transition curves, which provide a gradual change of the radius to the computed value.

#### § 61. EARTH ROAD BED

Usually the earth surface has unevenness, which when building the railroad is removed by the cutting or the piling on of soil.

Where the cutting of soil is necessary, cuts are developed, and where piling on is necessary - embankments are formed. Embankments, cuts and other constructions from soil, being raised when building the railroad, are called the earth road bed.

Under mountain conditions, so as not to develop large masses of soil, deep cuts are discarded and tunnels are built. At the intersection of deep ravines and valleys instead of embankments we construct cheaper constructions - viaducts. For the passage of a small quantity of water under the embankments we lay pipes. For the crossing of rivers we construct bridges. At the intersection of the railroad with automobile and other roads we erect overbridges. Tunnels, viaducts, tubes, bridges, overbridges are called artificial constructions. The earth road bed together with artificial constructions forms the substructure of the line. On it is placed the superstructure of the line: ballast prism, sleepers, bridge and crossing timbers, rails with attachments and anticreepers, turnouts.

Thus, the earth road bed serves as the base for the superstructure of the line. The earth road bed should be durable, stable, protected from deformations and shielded from the destructive effect of natural factors. In the majority of cases the earth road bed is erected on typical cross sections. The typical cross section of the embankment is depicted on Fig. 84.

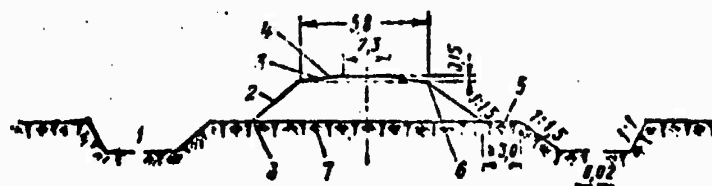


Fig. 84. Typical cross section of embankment: 1 - drainage ditches; 2 - slopes; 3 - main area; 4 - verges; 5 - berm; 6 - edge of embankment; 7 - base of embankment; 8 - bottom of embankment.

Part of the embankment, on which the superstructure is placed, is called the main area of the earth road bed. The width of the main area on straight sections of single-track railroads of III category is taken as 5.8 m. With rock soils there is allowed



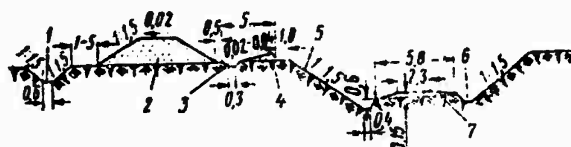
Fig. 85. Main area under one line: 1 - main area; 2 - ballast prism; 3 - verges; 4 - edge of embankment.

a 0.5 m decrease in the main area. The surface of the main area under one line is constructed in the shape of a trapezoid with height 0.15 m (Fig. 85). With such a contour of the surface of the main area water is not held on it. The surface of the main area in rock soils is

made horizontal. On the main area, to the left and right of the ballast prism, there are left strips called verges. They protect the ballast prism from crumbling, serve for the withdrawal of workers on them from the track before the passage of a train and for the placement of a tool. The side inclined surfaces of the embankment are called slopes, the joining line of the verge to the embankment slope - the edge. The strip of soil on which the embankment rests is called its base; the mating line of the embankment slope with the base - the bottom. For protection from destructive atmospheric effects the slopes are given a certain steepness, which depends upon the conditions of the soils, geological, hydrogeological and climate conditions of the locality. The slope steepness of embankments varies from 1:1.3 to 1:1.75. Along low embankments and with the absence of reserves we construct drainage ditches, protecting the embankments from surface water. The strip of soil between the bottom of embankment and drainage ditch is called the berm. It prevents the penetration of water from the ditch into the base of embankment. Width of berms is taken not less than 3.0 m.

Figure 86 shows the cross section of a cut. In the bottom part of the cut is constructed the main area under the superstructure of the line. From this area to the right and left are

constructed drainage ditches - ditches. The depth of ditches, as a rule, is 0.60 m, and width on the bottom 0.40 m. Outside the ditches are placed the slopes of the cut, which in clays, loams, sandy loams and sands are made with steepness 1:1.5; in coarsely fragmented soils (crushed stone, gravel and others) the slopes are given steepness from 1:1 to 1:1.5.



outside the zone of wave effect. In the areas of development of land slides antideformation measures are provided.

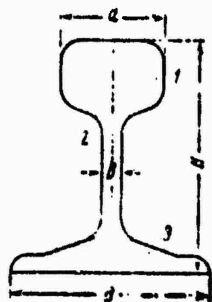
## § 62. MAIN ELEMENTS OF THE SUPERSTRUCTURE OF THE LINE

The superstructure of the line is designed for the receiving of loads from locomotives and cars and their transmission to the earth road bed. The main elements of the superstructure of the line include: ballast, sleepers, rails, crossing and bridge timbers, attachments, anticreepers, turnouts. The constructions of the superstructure of the line should be durable, stable, economical and ensure the safe passage of the rolling stock with the established loads and speeds.

The most critical element of the superstructure of the line is the rails. The rails directly absorb the effects of rolling stock and serve as guide filaments for the motion of locomotives and cars. For the construction of access railway lines there are used standard rails of type R43 (Fig. 87): height  $H = 140$  mm; width of head  $a = 70$  mm; width of flange  $B = 114$  mm, thickness of web  $b = 14.5$  mm; weight of 1 linear m 44.653 kg.

The rails are manufactured from rail steel, which ensures their sufficient rigidity, flexibility, hardness, wear resistance.

Fig. 87. Cross section of rail:  
1 - head; 2 - web; 3 - flange.



The rails should not be brittle.

The normal length of rails is 25 m; on the internal filaments of the curved sections of track are placed shortened rails 24.92 and 24.84 m long.

The rails are connected together with butt ties. With change of temperature the length of rails is changed, therefore between the ends of rails we leave clearances, which have maximum

structural magnitude 21 mm. The butt ties of rails consist of two plates, which overlap the ends of rails in the pocket between the head and flange on both sides and are tightened by bolts, passing into the openings of the plates of the rail webs. Under the nuts of bolts are placed spring washers, which prevent the loosening of bolts, which appears with the passage of trains.

The rails are placed on ties. The rails are connected with ties by intermediate fastenings: chairs, spikes or wood screws. The chairs are placed between the rail flange and tie. The chairs have spike holes. The two main spikes fasten the rail to the tie and two additional - the chair to the tie. The spikes are manufactured from hot-rolled square steel. The spikes slightly resist pulling out. Wood screws show considerably greater resistance to extraction. Under the action of rolling stock there occurs longitudinal movement of the rails over the ties, sometimes the rails together with ties, so-called rail creep. For the counteraction to rail creep there are anticreepers, which have special elements (wedges, clamps), counteracting the movement; spring anticreepers are used also.

The ties, as a rule, are wooden, made of pine, spruce, fir, larch, cedar, beech, birch. The ties are impregnated with wood preservatives.

The number of ties on 1 km of track on straight lines and curves with radius 1200 m and more is taken 1600-1440; on curves with radius less than 1200 m - 1840-1600.

As ballast there are used pit gravel, shell rock, asbestos and sand, which are placed on earth road bed in the form of a ballast prism. The thickness of all types of ballast is 30 cm. The width of the ballast prism on top on straight single-track sections is 3.10 m.

The steepness of the slopes of the ballast prism is taken 1:1.5, and for sand chair 1:2. The ballast prism is constructed 3 cm lower than the upper bed of wooden ties.

### § 63. SWITCHES

Switches serve for the transfer of rolling stock from one track to another. There is a number of varieties of switches which are characterized by the quantity and arrangement in the plan of the tracks being intersected, by the various types of rails, sorts of frogs and constructions.

Ordinary and symmetric single-switches received the greatest distribution. Ordinary single-switches (Fig. 88) are used for the turnout of the siding track from the main straight track.

Symmetric single-switches (Fig. 89) are used when both deflecting tracks are directed in different directions at identical angles from the main straight track. Single-switch consists of three main parts (Fig. 90): I - point with switching mechanism; II - switch tracks; III - frog with two guardrails.

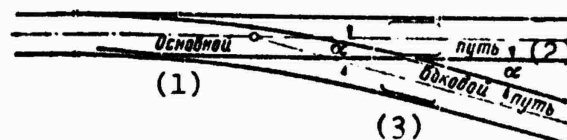


Fig. 88. Ordinary switches.  
KEY: (1) Main; (2) Track; (3) Siding track.

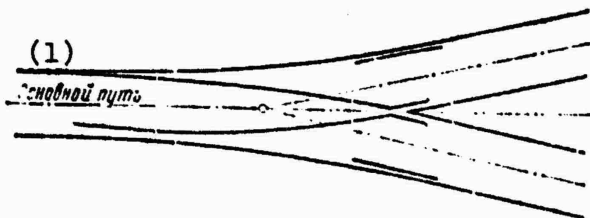


Fig. 89. Symmetric switches.  
KEY: (1) Main track.

The element of the first main part of the switch is the stock rails, which are manufactured from standard rails of normal profile. One of the stock rails of the switch is made curvilinear. For covering the edge of the tongue from impact with the wheel flange there is performed oblique planing of the side surface of the stock rail head (Fig. 91). Stock rails should be reliably fastened to switch



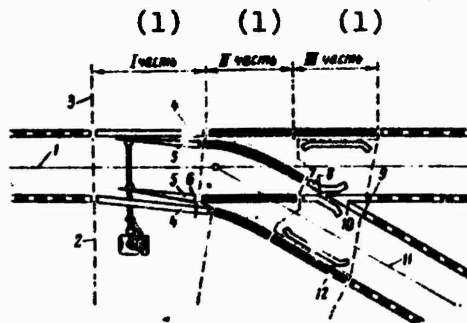


Fig. 90. Main parts of an ordinary switch: 1 - axis of the main straight line; 2 - front joint of stock rail; 3 - switch boundary; 4 - stock rail; 5 - tongue; 6 - heel of the tongue; 7 - front joint of the frog; 8 - guard rail; 9 - rear joint of frog; 10 - core; 11 - axis of siding track; 12 - counter rail.

KEY: (1) Part.

bars with the aid of switching shoes. The switching shoe consists of chair, switching chair with special recess for the stock rail chair and stops with parts for its attachment. The chair is fastened to the lining of the shoe with six rivets. The tongues are manufactured from special tongue rails which can have high and low profile. In the first case the height of the tongue rail is equal to the height of the standard rail. Tongue rails of low profile

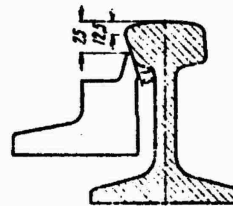
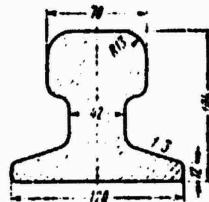


Fig. 91. Oblique planing of the stock rail and head of the tongue.

(Fig. 92) have high rigidity. To provide for the safe passage of rolling stock from one track to another the lateral face and tread contact surface of the head of the tongue is cut. The tongues are rectilinear: the first are used for siding track, and the second - for straight. The switching of tongues in the

Fig. 92. Cross section of type OR-43 switch rail.



majority of switches is accomplished because of their turning in the heel without bending of the tongue itself. Sometimes in new switches there are used flexible tongues: during switching such a tongue is elastically bent within a specially weakened section.

Heel attachments in this case are constructed stronger and

stabler. The heel devices are designed for attachment of the tongue in the heel and providing its horizontal movement when switching from one position to another. In the majority of switches there is used insert-plate heel attachment of tongues (Fig. 93). The joint in the heel is mounted on a steel bridge, which is fastened to beams with wood screws. Butt joints consist of a four-hole steel insert and cover plate. The cover plate, tongue with the rail of shifting tracks adjacent to it, insert and stock rail are connected by four bolts.

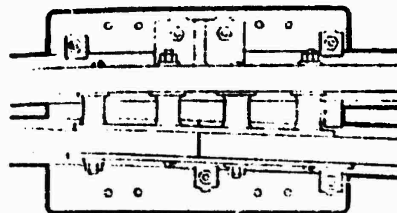


Fig. 93. Insert-plate heel attachment of the switch rail.

In the case of flexible tongues we use ordinary plate heel attachments, whose construction is as good as the construction of ordinary standard track joint. The heel joint and flexible part of the tongue in this case are mounted on a steel plate 20 mm thick. Switching mechanisms switch the tongues from one position to another with the aid of mechanical, electrical or manual switching devices.

The switches in the working position should be reliably locked. For locking the switches with manual operation we use control locks of the Melent'yev system. Furthermore, they are supplemented with hinged linings, being locked on a padlock. In centralized switches the tongues are locked by an electric drive. Besides the main components, the switches and switching mechanisms are equipped with a number of additional parts. Connecting strips ensure constancy of gauge between stock rails, switch rods - transverse connection between tongues.

Switching tracks - second main part of switches. The switching tracks consist of outer and inner filaments. The first are placed

from the rear joints of stock rails to the end of the switch, the second - from the heel joints to the frog. Ordinary switches have one switching track straight, and another curvilinear; symmetric switches have both switching tracks curvilinear. The attachment of rails on switching tracks is accomplished by spikes and wood screws. With spike attachment of the track each chair is lined with five spikes.

The frog is the third main part of the switch. It ensures the safe passage of wheels of the rolling stock at the points of intersection of rail filaments. The basic parameter which characterizes the frog is the so-called mark of the frog. By mark of the frog there is meant the tangent of the angle formed by the intersection of axes of the main and siding track  $\text{tg } \alpha$ . In ordinary switches there are used frogs with marks  $1/22$ ,  $1/18$ ,  $1/11$  and  $1/9$ ; in symmetric switches - marks  $1/11$ ,  $1/9$  and  $1/6$ . The frog of single switches consists of the core and two guide rails. With respect to construction the frogs can be assembled with the cast cores, unit-cast from high-manganese steel and assembled from rails. The frogs are equipped with two counter rails, which are manufactured from section iron. The counter rails guide the wheels of the rolling stock during their passage over the frog and they do not allow the impact of the flanges of wheels into the point of the core during movement from the switch to the frog. The ends of the counter rail in the plan have a mildly sloping bend, which decreases the impact of wheels in the counter rail. The axes of the counter rail and track rail are parallel.

The track rail and counter rail are connected by counter-rail bolts and inserts and are placed on flat chairs (Fig. 94). The chairs are fastened to beams by spikes or wood screws. Inside the counter rails are installed stops, which provide the constancy of the gauge in the frog.

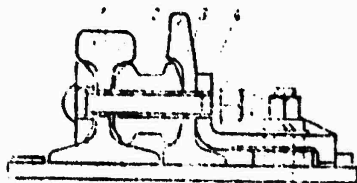


Fig. 94. Counter rail assembled with track rail:  
1 - washer-insert; 2 - insert; 3 - counter rail;  
4 - stop.

The switches are the most critical part of the superstructure of the track. Therefore serious attention should be given to the maintenance of switches.

#### § 64. PRINCIPLES OF SIGNALING, CENTRALIZATION AND BLOCKING

For organization of the safe movement of trains the railroad lines have been divided in sections, called open lines. The points which divide the railroad lines into open lines are called blockposts. They are made in the form of stations, sidings, track towers and passage signal lights.

Three types of open lines are distinguished: between stations, between towers and block-sections. The boundaries of the first are the stations and sidings; the second - line towers or a tower and station; the third - passage signal lights on lines equipped with automatic blocking. The basis of the safety of movement of trains on the railroad transport is the requirement that on one open line or block-section there be only one train, and the reception of trains on the blockpost be accomplished only after careful check of the emptiness of the track.

The technical equipment, with the aid of which there is accomplished control and safeguarding of the movement of trains at railroad stations, open lines and block-sections, received the name signalization, centralization and blocking (STsB) devices. The STsB devices depending on their purpose are subdivided into open line and station. The open line devices are designed to provide the safe movement of trains on open lines. They include

semiautomatic and automatic blocking systems. With semiautomatic blocking the reception and dispatching of trains are accomplished by a man; the arrival of a train at the blockpost is recorded on the station control panel automatically by the train itself. With automatic blocking the passage signal lights operate without a man.

For the full guarantee of the safety of movement both blocking systems are supplemented with automatic locomotive signaling devices, with which in the engine cab there are installed a locomotive signal light, and a self-locking device, not allowing the throughfare of a forbidding signal. Open line devices also include automatic crossing signaling (light signal and describer) and automatic lifting barriers.

The station devices of STsB provide the safety of movement of trains at the stations. They include: route control systems, which allow the assistant stationmaster to check the correctness of preparation of routes by the switching towers with manual control; the mechanical centralization of the switches and signals, with which the switches and signals are controlled from the equipment of the central tower with the aid of levers, connected by flexible rods with the switch and signal drives; electric centralization of switches and signals, with which the switches and signals are controlled from a central station with the aid of electric current; centralized traffic control, at which switches and signals of the whole railroad section (stations and open lines) are controlled from one point.

To ensure the safety of movement of trains there are visual and audible signals. The visual signals are marked by color and by the position of signal indexes. For the supply of visual signals we use signal lights, semaphores, lanterns and flags. The following basic types of signal colors are used: red - requires stop; yellow - permits movement with readiness for stop

at the following signal, which has forbidding indication; green - permits movement at a set speed. Audible signals are supplied by the whistles of locomotives, horns, sirens and hand whistles.

Three systems of semiautomatic blocking are used: electro-mechanical, in which as the main closing element there is a block-mechanism, which is the electromechanical alternating-current gate; blocking with polar linear circuit, in which the closing element is an alternating-current electric gate; semi-automatic relay blocking, in which as the closing device there is a direct-current relay. The automatic block system ensures the automatic opening and closing of signal lights under the action of the moving trains themselves. The connection between the moving trains and the passage signal lights is accomplished with the aid of electric track circuits, which at the beginning and end of the block section are insulated from one another.

The basic instrument, which closes and opens the electric circuits, is the direct- and alternating-current relay.

Station route control systems include apparatuses with control switch and signal locks. Key switch control locks close the switch with the aid of a key, power - with the aid of the lever of the flexible gearing line. Signal locks have a construction similar to the construction of switch locks.

The mechanical centralization of switches and signals makes it possible from centralized stations with the aid of the centralization of control devices to control the power locking mechanisms of switches and semaphores with the aid of flexible gearing. The control range of switches can reach 800 m, and semaphores - 1500 m. Recently, with the presence of electric power at the station, instead of semaphores signal lights began to be used.

Electric centralization includes a number of devices for the centralized control of switches and signals: centralized apparatus, illuminated indicator board with the image of the track layout; relay; switch electric drives for switching, closing and monitoring of the position of point rails, cable systems and others. Centralized traffic control combines the devices for automatic blocking on open lines and electric centralization of the switches and signals at stations. The objects are controlled with the aid of various translational devices. Centralized traffic control makes it possible to increase the throughput capacity of single-track sections by 25-35% as compared with other means of signaling and to considerably reduce the staff of maintenance personnel. Therefore this type of centralization has great prospect.

Selection of the type of signalization, centralization and blocking devices of access railway lines depends upon the technical equipment of existing railroads, extent of provision for electric power and is accomplished upon agreement with the departments of the Ministry of Railroads.

**SECTION II**  
**MAINTENANCE AND REPAIR OF AIRFIELDS**



## CHAPTER XV

### THE ORGANIZATION OF OPERATIONS OF MAINTENANCE AND REPAIR OF AIRFIELDS

#### § 65. MISSIONS OF AIRPORT SERVICE

Airport service is called on to provide constant preparedness of the airfield for the flights of aircraft at any time of the year and day. It is attained by technically correct operation, systematic care of constructions, the performance of routine maintenance of the flying field, artificial coverings, buildings and constructions, access and interairport roads, and also by the timely preparation of airport working vehicles for operation.

Therefore the main missions of the airport service are: preparation for operation, the maintenance and routine repair of flying field and artificial coverings, sewer-drainage systems, access and interairport roads, and also all constructions of the office and technical building system. As a result of the careful operation and timely repair the service life of the separate elements of the airfield is increased and the preconditions for takeoff and landing emergencies of aircraft are eliminated.

#### § 66. BASIC MAINTENANCE REGULATIONS OF AIRFIELDS

The maintenance of airfields in constant flight readiness provides for a complex of measures connected with the provision for

the daily care of constructions, organization of repair of the flying field and the observance of established maintenance regulations of airfields.

On airfields there is forbidden: movement of all types of transport in a random direction; the movement and operation of tracked transports without rubber linings on the tracks; the grazing of cattle.

The movement of personnel and all transportation means over the airfield is allowed only on established routes, which should be designated by single traffic signs. The time of performance of works on the routine repair of the airfield is coordinated with the airport manager.

On unpaved airfields care of the flying field with sod covering, the packing of roughness, tracks and potholes are accomplished right after the termination of flights. The working area of the unpaved flying field should be developed into three or four flying strips 40-45 m wide each. During operation of one of the strips on the others there is performed restoration of the sod covering, the elimination of small roughness and tracks, and also a decrease of dustiness. The duration of operation of each flying strip depends upon the intensity of flights, landing gear and type of aircraft, upon the strength of the soil and quality of the sod covering.

With an insufficient quantity of unpaved flying strips and considerable length of the flying field it is advantageous to periodically move the takeoff point 150-200 m along the strip.

The operation of flying strips is not allowed with over-moistened soils and with soil strength less than permissible for the given types of aircraft or helicopters. With weak soils

on the MS of aircraft and helicopters under the wheels it is necessary to place metal plates or wooden panels.

On airfields which have RW, RD and MS with artificial covering the flights of aircraft and helicopters, for which such a covering is not designed, are forbidden, it is impossible to perform flights from RW having defects, which can cause breakage of aircraft and helicopters.

For determining the possibility of the operation of new aircraft from artificial coverings the airfield covering is evaluated. The decision about the suitability of the covering for operation by new types of aircraft is made after the comparison of the required strength of the covering with actual. The required strength of the covering is determined by special calculation, which is performed in accordance with Specifications on the design of airfield coverings (SN-120-60).

Before the start of flights from the airfield a thorough inspection of RW, RD and ramps should be conducted. If in this case defects are detected, especially on the RW, then flights are not permitted. On the RW there should not be untreated chips of corners and edges of slabs, or drops between slabs more than 5 mm. On the surface of the covering there are not allowed fragments of concrete, crushed stone, sand, mud and foreign objects. In winter there should not be snow or glare ice on the coverings.

The suitability of unpaved flying field for flights is determined basically by the strength of the unpaved surface and by its evenness. Airfield radio and signal equipment should operate well. During the period of snow melting, rains and bad roads at airfields special crews should be created for working on drainage, monitoring the water drainoff devices and the prevention of flooding of artificial coverings by water.

Before the onset of stable temperatures below the freezing point and the falling of snow it is necessary to repair the flying field of the airfield, constructions of office and technical building system and airfield working machines, to prepare the missing quantity of winter towing technology, to organize the training of personnel of the airfield subdivisions with the latest methods and the methods of airfield maintenance during the winter period.

#### § 67. THE RESPONSIBILITIES OF OFFICIALS

The provision of constant operational readiness, timely and qualitative conducting of repair of airfields, artificial coverings of RW, RD, MS, ramps, roads, buildings and constructions of the airport is accomplished by officials of the subdivisions of the GVF - by the territorial control manager, his deputy on ground service and divisions of ground constructions.

The constant operational readiness of the airfield, the execution of plans of repair and maintenance of flying fields, constructions and buildings of the airport are directly ensured by the airport manager with the aid of the airfield service of the airport.

The workers of airfield service provide the maintenance of the flying field and constructions of office and technical building system of the airfield in constant readiness for takeoff regardless of the time of day and year. The works on the maintenance and routine repair of the flying field and constructions of the office and technical building system of the airfield are planned so as to maximally use the time free of flights for this. Personnel should also be taught for working at night, when the intensity of flights is less than in the daytime.

The responsibility of the airfield service workers also includes the maintenance of airfield equipment and the timely production of the simplest means of mechanization. When performing works on the routine repair and maintenance of the flying field the foremost procedures and methods for organization of the work should be introduced. In this case it is necessary to attain the economical expenditure of monetary means, fuel, structural materials and lubricants, grass seeds and mineral fertilizer, using them only according to the direct purpose for the needs of the routine repair and maintenance of flying fields and constructions of office and technical building system.

The airfield service manager should accomplish technical supervision of the flying field and constructions of the office and technical building system of the airfield, and also the routine monitoring of the strength and evenness of the unpaved part of the flying field, should keep a journal of test data of the strength of soil and evaluation of the surface evenness; he draws up defect reports, composes the annual and monthly plans for the maintenance of artificial coverings, the flying field and constructions of office and technical building system of the airfield, keeps the journal of the airworthiness of RW, RD, MS, airfield log book; develops the condition of operation of the flying field of the airfield (the takeoff and taxiing points of aircraft), order of movement of motor transport and airfield operation technology, coordinates the time of conducting airfield operation and repair works and presents the plan for operation of the flying field to the manager for affirmation. Among the responsibilities of the airfield service manager are also the monitoring of accomplishment of the fire protection requirements and the observance of traffic rules of people and motor transport over the airfield, monitoring the presence of obstruction lights and landmarks on high obstructions.

All disturbances of the conditions of operation of the flying field and order of movement in the airfield zone, and also violations of the rules of operation of constructions of the office and technical building system are reported by the airfield service manager to the airport manager and measures are taken for their immediate elimination.

## CHAPTER XVI

### MAINTENANCE AND REPAIR OF UNPAVED FLYING STRIPS

#### § 68. CHARACTERISTIC DEFORMATIONS AND FAILURES OF UNPAVED FLYING STRIPS AND METHODS OF MONITORING THEIR CONDITION

Under the effect of climate factors, and also aircraft and the airfield servicing facilities the surface of unpaved flying strips is deformed and broken. The surface strength of unpaved flying strips highly changes with change in the moisture of soil. A reduction in the soil strength lower than that required makes its further operation impossible.

The evenness of the surface of flying strips is estimated according to the magnitude of unevenness. It is accepted to distinguish the following types of unevenness: mesoroughness (waviness, pimple and holes on sections up to 40 m long), caused by seasonal displacements of soil or by the action of aircraft, and also by the poor quality of earth works, the packing of soil heterogeneous in density; microroughness (wheel tracks, potholes, fine pimples, minor depressions, etc., on sections up to 3-5 m long). In some areas of our country the evenness of the flying field can disturb burrowing animals.

During the maintenance and repair of unpaved flying strips the strength of soil and evenness of the surface are constantly

checked. The suitability of unpaved flying strip for takeoffs and landings with respect to strength and evenness is established by comparison of the measured values with permissible. The strength of the soil of the flying field should be monitored systematically with the aid of the hand instrument striker U-1 (Fig. 95).

Fig. 95. U-1 striker: 1 - rod-tip 11.2 mm in diameter (area of cross section 1 cm<sup>2</sup>) and long working part 300 mm, divided by graduation marks into three parts 100 mm each; 2 - a weight weighing 2.5 kg; 3 - guide for the movement of the weight to a height of 500 mm from the cap of the point; 4 - handle.



The striker is placed into the soil vertically by the point, the weight is raised along the guide upward to the stop and, by lowering, is left to freely fall along the guide. By striking the cap, the weight drives the point into the soil. The dropping of the weight is repeated until the tip is driven into the soil 30 cm (to the mark). During tests there is computed the number of drops of the weight for insertion of the tip 10 cm ( $n_{10}$ ) and by the accumulating sum to 30 cm ( $n_{30}$ ). For determining the soil strength the test is conducted twice at points 1-2 m from each other. In the case of considerable divergence of the results of two tests (for  $n_{10}$  more than two impacts, and for  $n_{30}$  more than 20%) it is necessary to conduct a third test. Then by the two most similar of the three results determine the mean value for  $n_{10}$ , and also for  $n_{30}$ . If during the test the tip hits crushed stone or other solid objects in the soil, the test should be stopped and repeated 0.5-1 m from this place. By the obtained mean values of the numbers of impacts for insertion of the tip 10 cm ( $n_{10}$ ) and 30 cm ( $n_{30}$ ) with the aid of



Table 64 establish the strength of the top layer of soil (at depth 10 cm)  $n_{10}$  and underlying layer (at depth 30 cm)  $n_{30}$  at every place of tests.

Every test by the U-1 striker gives spot determination of the strength of soil. Double and triple determination characterizes the strength of soil on a small section. The various indications of strength on separate sections of LP are explained by the different degree of moisture and compaction of soil, and also by the different granulometric composition. In connection with this the soil test by the striker should be conducted over the entire working area of the unpaved flying strip. The unpaved flying strip, RD and MS are divided into  $25 \times 25$  m squares and at the corners of the grid of squares, and also in all doubtful places we determine the strength of the soil. Based on the materials of this examination one should conduct thorough soil compaction or planning operations to provide for the runoff of precipitation.

The systematic tests of soil strength, being carried out on the flying strip, should be conducted on its working area: along the length - on end (takeoff) sections 300 m long, every 50 m, and in the middle every 200 m; along the width along the axis of each takeoff area, which has width not over 50 m.

The results of tests by the striker are recorded in a special log. The processing of the results of measurements of soil strength consists of the following:

a) the indications of striker  $n_{10}$  and  $n_{30}$  are converted into the soil strength  $\sigma_{10}$  and  $\sigma_{30}$  ( $\text{kgf/cm}^2$ ) with the aid of Table 64, having predetermined the type of soil and ground;

b) the strength of soil is determined for every place of tests by two determinations of the striker, as the average of them:

Table 64

I - fine-sand, sand silty, sandy loam, fine sandy loam						II - silty loamy, heavy loamy silty-loamy						III - chernozem, chestnut, brown saline					
$n_{10}$	$\sigma_{10}$	$n_{30}$	$\sigma_{30}$	$n_{10}$	$\sigma_{10}$	$n_{10}$	$\sigma_{10}$	$n_{30}$	$\sigma_{30}$	$n_{10}$	$\sigma_{10}$	$n_{10}$	$\sigma_{10}$	$n_{30}$	$\sigma_{30}$	$n_{10}$	$\sigma_{10}$
1	3.9	7	3	29	11.9	1	1.5	29	11.9	1	1.5	1	1.5	29	1.4	7	9.5
2	4.8	8	4.5	30	12	2	2.2	30	12.1	2	2.5	2	2.8	30	1.5	8	9.7
3	5.3	9	5.3	31	12.1	3	3.4	31	12.2	3	3.5	3	4	31	1.6	9	9.8
4	5.8	10	6.2	32	12.2	4	4.7	32	12.3	4	4.5	4	5.7	32	1.8	10	10
5	6.2	11	6.8	33	12.3	5	5.8	33	12.4	5	5.5	5	6.8	33	1.9	11	10.3
6	6.8	12	7.3	34	12.4	6	7	34	12.5	6	6.5	6	7.8	34	2.2	12	10.6
7	7.3	13	7.8	35	12.5	7	8.7	35	12.6	7	7.2	7	8.8	35	2.8	13	10.7
8	7.8	14	8.4	36	12.6	8	9.5	36	12.7	8	8.1	8	9.2	36	3.2	14	10.8
9	8.4	15	8.7	37	12.7	9	10.2	37	12.8	9	9.4	9	10.5	37	3.8	15	11.0
10	8.7	16	9.4	38	12.8	10	11.2	38	12.9	10	10.8	10	11.1	38	4.3	16	11.1
11	9.4	17	9.8	39	12.9	11	12	39	13	11	11.2	11	11.6	39	5	17	11.3
12	9.8	18	10.3	40	13.1	12	13	40	13.1	12	12.9	12	12.1	40	5.5	18	11.5
13	10.3	19	10.7	41	13.2	13	13.8	41	13.2	13	13.1	13	13.1	41	6	19	11.7
14	10.7	20	11.2	42	13.3	14	14.5	42	13.3	14	13.1	14	13.1	42	6.4	20	11.9
15	11.2	21	11.5	43	13.4	15	15	43	13.4	15	13.2	15	13.2	43	7.3	21	12.1
16	11.5	22	12	44	13.5	16	16	44	13.5	16	13.4	16	13.4	44	7.9	22	12.2
17	11.7	23	12.5	45	13.6	17	17	45	13.6	17	13.5	17	13.5	45	8.3	23	12.3
18	12	24	13	46	13.7	18	18	46	13.7	18	13.6	18	13.6	46	8.9	24	12.5
19	12.5	25	13.5	47	13.8	19	19	47	13.8	19	13.7	19	13.7	47	9.2	25	12.6
20	12.8	26	14	48	13.9	20	20	48	13.9	20	13.9	20	13.9	48	9.5	26	12.8
21	13.1	27	14.5	49	14	21	21	49	14	21	14	21	14	49	9.7	27	12.9
22	13.2	28	15	50	14	22	22	50	14	22	14	22	14	50	10	28	13
23	13.3					23	23			23		23					
24	13.4					24	24			24		24					
25	13.5					25	25			25		25					
26	13.6					26	26			26		26					
27	13.7					27	27			27		27					
28	13.8					28	28			28		28					
29	13.9																
30	14																

Note.  $n_{10}$  - number of drops three for insertion of the tip 10 cm;

$n_{30}$  - the same, 30 cm and the strength of soil respectively

$\sigma_{10}$  and  $\sigma_{30}$  kgf/cm<sup>2</sup>.

$$\sigma_{10}^p = \frac{\sigma_{10}' + \sigma_{10}''}{2}; \quad \sigma_{30}^p = \frac{\sigma_{30}' + \sigma_{30}''}{2};$$

c) the strength of soil is determined on the section (100-meter)  $\sigma_y$  as the average of the strength of the upper  $\sigma_{10}^{cp}$  and underlying  $\sigma_{30}^{cp}$  layers by formula

$$\sigma_y = \frac{\sigma_{10}^p + \sigma_{30}^p}{2} \text{ kgf/cm}^2. \quad (79)$$

The strength of the soil on each takeoff area of the flying strip on the whole is determined by the formula provided below, for which of all the obtained values of  $\sigma_y$  on the given takeoff area there are selected the smallest, the number of which should be equal to half of all the places of measurements, and from them is calculated the average

$$\sigma_{cr} = \frac{\sigma_y' + \sigma_y'' + \sigma_y''' + \dots + \sigma_y^n}{0.5m} \text{ kgf/cm}^2. \quad (80)$$

where  $\sigma_y'$ ,  $\sigma_y''$ ,  $\sigma_y^n$  - smallest strength indices of soil  $\sigma_y$ , total amount of which is equal to half of all places of tests on a given takeoff area;

m - the quantity of all tests conducted on the soil strength on the given takeoff area.

The individual places, on which the soil strength index  $\sigma_y$  was less than strength index  $\sigma_{cr}$  on the takeoff area on the whole, will be subject to additional inspection for the purpose of establishing the necessary measures for improvement (strengthening) of the soil (packing, draining, the filling of soil, etc.).

The evenness of the surface of flying strip depends upon vertical displacements of the top layer of soil with seasonal freezing and thawing, upon the duration and intensity of the operation of aircraft on the flying strip, and also on the quality of planning works during building and repair.

Monitoring the surface condition of unpaved flying strips is reduced to the revealing of unevenness, the magnitude of which

exceeds maximum permissible values. On the sections of defective mesorelief one-two characteristic directions are selected, by which leveling surveys of the profile are made with spacing 5 m. The leveling is recorded in a special log.

From the results of leveling survey there are calculated the gradients of straight segments, connecting the leveling points with 5 m spacing, then the gradients of straight segments connecting the points 10 m from one another and further 20 m (Fig. 96).

The gradient is determined by formula

$$i_a = \frac{h_n - h_{n-1}}{a}, \quad (81)$$

where  $i_a$  - gradient of the straight segment connecting the points  $a$  meters distant;

$h_{n-1}$  - mark of the previous point of leveling survey;

$h_n$  - mark of the following point;

$a$  - the distance between the previous and following points, m.

The  $i_a$  has a "plus" sign, if in the course of survey rise ( $h_n > h_{n-1}$ ), and "minus" sign, if decrease ( $h_n < h_{n-1}$ ).

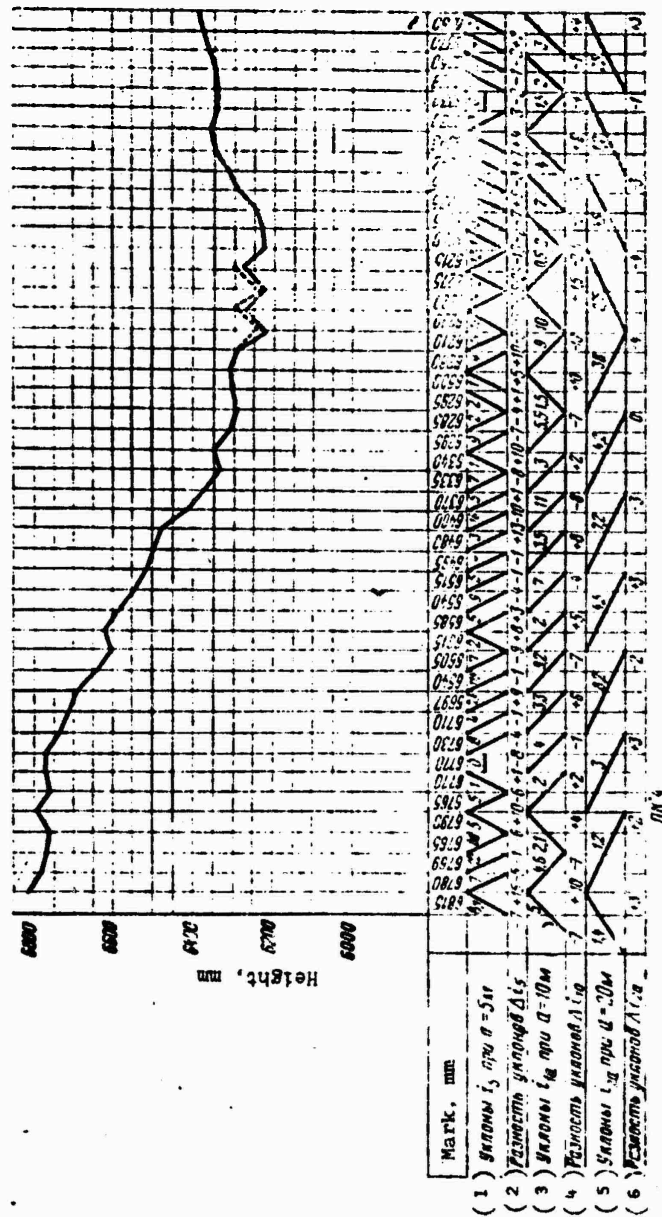
After the computation of gradients there are calculated the differences of the adjacent gradients of straight segments with length 5, 10 and 20 m using formula

$$\Delta i_{(5,10,20)} = i_{n-1(5,10,20)} - i_{n(5,10,20)}, \quad (82)$$

where  $\Delta i_{(5,10,20)}$  - algebraic difference of adjacent 5, 10 and 20-meter segments;

$i_{n-1}$  - gradient of the previous segment with its sign;

$i_n$  - gradient of the following segment with its sign.



KEY: (1) Slopes  $i_5$  when  $a = 5m$ ; (2) Difference of slopes  $\Delta i_5$ ;  
 (3) Slopes  $i_{1a}$  when  $a = 10m$ ; (4) Difference of slopes  $\Delta i_{10}$ ;  
 (5) Slopes  $i_{2a}$  when  $a = 20m$ ; (6) Difference of slopes  $\Delta i_{20}$ .

From the results of the leveling survey of an unpaved flying strip there is constructed a profile, on which there are marked the places with inadmissible discontinuity of relief ( $\Delta i$ ).

The limiting values of mesoroughness, with the achievement of which repair of the unpaved flying strips should be accomplished, are the following:  $\Delta i_5 = 0.030$ ;  $\Delta i_{10} = 0.022$ ;  $\Delta i_{20} = 0.015$ .

After the repair of the unpaved flying strip the evenness of the surface should correspond to the requirements of § 258 of the Specifications of production and acceptance of airfield construction works (SN 121-60):  $\Delta i_5 = 0.020$ ;  $\Delta i_{10} = 0.015$ ;  $\Delta i_{20} = 0.010$ .

Microroughness should not exceed 4 cm with placement of a 3-meter rod on the surface. The evenness of each takeoff area of the working area of the flying strip is checked simultaneously with determination of the soil strength. Furthermore, the evenness of the surface of flying strip is checked: on the entire flying strip in the spring after the thawing of soil to a depth of 50 cm; selectively at the places of aircraft movement after flights or the intense traffic of other machines over the unpaved flying strip, especially on the takeoff sections. The results of checking the evenness of the surface of the flying strip are recorded in a special log.

From the results of determining the soil strength and evenness of the surface there is established the suitability of the flying strip for operation by a given type of aircraft. If necessary the suitability of the unpaved flying strip or its separate sections for operation can be checked by the test taxings of aircraft.

§ 69. METHODS OF OPERATIONAL  
MAINTENANCE AND REPAIR OF UNPAVED  
FLYING STRIPS

The repair of unpaved flying strips consists of restoration of the sod covering and elimination of fine unevenness (wheel tracks, potholes, sags, ravines, "minor depressions," pimples and others), which exceed the maximum permissible values.

On flying fields without sod covering and also sodded RW, whose operation will be continued soon after repair, the main type of work is the elimination of unevenness. The restoration of existing and the creation of new sod covering in this case are not always advisable, since for the adherence of sod and the growing of grass and sod formers a long period is necessary, calculated in several months.

During the repair of flying fields which will not be operated for several months, works are carried out both on the elimination of unevenness and on the restoration of sod covering. Among the basic types of works on the elimination of unevenness are: earth works (delivery of soil or its movement to short distances); grading of the surface of flying fields; soil compaction.

For the filling of fine unevenness it is necessary to use soils, with composition and quality corresponding to those soils which are located in the sections of the flying field being repaired. The soil is delivered to the places of repair by dump trucks, scrapers, by means of movement by bulldozers (to distances up to 30 m). In the absence of bulldozers and scrapers graders can be used. Soil is loaded into dump trucks by excavators or tractor loaders.

The delivered soil is poured into low places and immediately leveled by bulldozers, motorized road graders. It is not possible

to leave the delivered soil until the following day, since in the course of time it loses natural moisture and in dried-up state it is very difficult to compact.

Small potholes are sealed by means of filling with topsoil and grading by hand. The sealing of ravines and "minor depressions" is produced by loosening the soil with shovels or disk harrows to a depth of 10 cm with the subsequent addition of uniform topsoil, which is leveled, mixed with local loosened soil and thoroughly compacted first with light, and then with heavy rollers.

During elimination of large slanting "minor depressions," filled with water, water is preliminarily drained from them by the construction of drains or filter wells. Small tracks (with depth up to 5 cm) are filled up by their usual pressing with pneumatic rubber or metal rollers. The filling of deep single tracks is produced by two opposite passes of a motorized road grader, at which the blade is set at a 45-60° angle with subsequent rolling.

While filling up the low places, it is necessary to avoid excess addition of soil, since its compaction always presents known difficulties. After the preliminary smoothing of the dropped-off soil we grade the surface of the sections of the flying field being repaired by motorized road graders, trailer graders, long-base planers.

While grading on the sodded sections of the flying field for the avoidance of damage to the sod covering it is especially necessary to keep a high position of the cutting edge of the operating unit of the planing machine. The minimum distance from the cutting edge to the sod surface should be not less than 3 cm.



During the repair of the areas of the takeoff and landing sections of RW, considerable with respect to dimensions, where the area of destruction of the sod covering reaches 30% and more, and its restoration in shortened periods is practically unrealizable, for the achievement of uniform redistribution of soil on the section being graded it is necessary before the grading to break up the sod by means of disking or scarifying.

With continuous planing of areas considerable in dimensions the most rational scheme of organization of works is circular passes with the grader from the boundaries of the section to its middle. Each pass of the motorized road grader should overlap the previous track 20-30 cm.

After preliminary planing we compact the soil with light pneumatic rubber rollers, and then with smooth metal rollers; this makes it possible to immediately detect the defects of microrelief, which we correct during final surface finishing. The final planing of the surface of the sections of LP being repaired is accomplished by several passes of a motorized road grader, or one-two passes of a long-base planer and is alternated with compacting by light rollers.

Among the basic types of repair work in the restoration of sod covering are the transplantation of sod and the sowing of grass and sod formers. The preparation of sod for transplantation is produced on sections located outside the flying field. On the section of preparation of the sod before its cutting the herbage should be bevelled to the height of the stubble, not exceeding 8 cm.

The sod is cut into strips 20-30 cm wide, 1-1.5 m long and 5-6 cm thick. The sod is cut out with a plough. Other attachments can be applied. Before the transplantation of sod the section being repaired is filled with topsoil, without bringing the level

of filling 3 cm to the surface of the soil. Then the soil is loosened to a depth of 5-7 cm, the sod is tightly placed on it and compacted by light rollers. With the transplanting of sod in dry weather the soil is wet with water before laying the sod at a calculated rate of 15-20 liters per 1 m<sup>2</sup>.

To provide for the rapid development of new sprouts and root system in the implanted turf it is advantageous to water it with a solution of mineral fertilizers.

The restoration of the sod covering by means of sowing grass and sod producers is advantageous in the case when the sod covering has been destroyed on a large area or has thin herbage. With the sowing of grass the herbage available in the repairable sections is mowed to a height of 5 cm. Then over the surface of the section is scattered mineral fertilizers. After that the soil is loosened by a disk harrow. With sandy loam and sandy soils instead of disking it is sufficient to harrow with tooth harrows. After this the areas being repaired are sowed with grass seeds. For sowing it is recommended to use grass mixtures, which should include grasses of three basic biological groups: rhizome, loose and close shrub and rod-root from the following: in forest-meadow and forest-steep zones - pasture rye grass, awnless brome grass, red fescue grass, mixed orchard grass, white and ordinary bent grass, white clover; in the steppe zone - awnless brome grass, yellow alfalfa, narrow-ear and broad-ear wheatgrass, and also fescue (furrowed fescue).

The sowing of grasses should be accomplished during the moist period of the year - early spring and during the summer-autumn period, but not later than the optimum periods of sowing of winter grains in the given area. Spring sowings are accomplished in the first 4-5 days of sowing of early cereals.

Sometimes, when a large amount of precipitation falls, summer sowings of grass can be accomplished. The sowing of grasses on the sections being repaired is performed by broadcast grain-grass or grain seeders. Plowshares are removed from the latter and the seeds are scattered randomly through free-hanging seed-drives. The sowing of seeds of grasses is allowed by hand. In this case the seeds are preliminarily mixed with sawdust, sand or with dry decomposed peat in 1:2 proportion.

Grass seeds are sowed in two stages - crossed. First in one direction we sow a mixture of large seeds (awnless brome grass, meadow fescue, rye grass and others) and lay in a "zigzag" with a harrow into one-two tracks, and then across we sow small seeds (meadow timothy grass, meadow grass and others), which are covered up with a brushwood rake.

When sowing grass mixtures which consist of one group of seeds (large or small), they are also sowed in two stages: half of the norm lengthwise, and the second half across the section being repaired. With hand seeding of small areas the seeds are set into the ground by rakes. After the setting of seeds the sowed sections must be slightly compacted by a light roller, which facilitates the accelerated intergrowth of seeds. In a dry time the sowed sections should be wetted until soaking of the top layer of soil to a depth not less than 2-3 cm and then slightly covered with loose humus or compost with a 2-3 mm layer.

On large areas with thin herbage the grass seeds can be sowed directly into the sod (without preliminary loosening of the ground with a disk harrow) with subsequent compacting by light rollers. In this case for the uniform distribution of seeds in the soil their sowing norm is divided into four parts and sowing is accomplished in four mutually perpendicular directions. Compacting with a light roller should be performed on the day of sowing.

The repair of sod covering on flying fields, besides the sowing of grass seeds and the transplanting of sod, can be accomplished by the vegetative method. For this on the section (outside the flying field) with grass-sod producers it is necessary to loosen the sod covering with a rotary cultivator. The pulverized parts of the plants are collected in piles, loaded in dumptrucks and transported to the sections being repaired, where we prepare the soil in advance, the same as for sowing grass. The pulverized parts of rhizome, sprouts must be evenly distributed over the surface, then covered over in the soil by rakes or a tooth harrow, pour ground on top with a layer 0.5 cm and compact with a roller. If there is no precipitation, the surface after the planting of vegetative parts in the ground and after rolling it is necessary to pour on water. The vegetative method of obtaining a sod covering during a short period (especially when using sprout-forming bent grass and red fescue) allows creating the most durable sod as compared with sowing of seeds.

#### § 70. METHODS OF STRENGTHENING THE SOILS OF THE FLYING STRIP

Increase of strength and resistance of soil to soaking are attained by the timely compaction of the surface of the flying field in conjunction with the provision for rapid runoff of precipitation and thaw water outside the flying strip. The best effect of compacting is attained with optimum moisture of the soil. Such a condition of the soil is, as a rule, in the spring and autumn during the rainy period.

Soil compaction should precede the following measures: inspection of soils on the sections planned for compacting; determination of the granulometric composition, maximum density and optimum moisture for the characteristic varieties of soils; through planing and repair of the surface of sections of compacting with complete elimination of wheel tracks, minor depressions, potholes, hillocks, etc.

On the flying field are determined the sections with soils uniform in granulometric composition. On each of the sections on an area of 5 ha there are placed two or three holes to a depth up to 1 m. The outlines of the sections are determined with the aid of heelings 30 cm deep at a rate of 5-10 heelings per 10 ha. The soil differences with respect to the granulometric composition under field conditions are determined for each hole.

For the selection of the periods of soil compaction and for determining the required density, at which the least expenditures of efforts and facilities are possible, by the taken samples we determine the maximum density and optimum moisture by the standard or accelerated method. The required soil density is determined depending on the maximum density, obtained by the method of standard compacting.

The RW is compacted by rollers on pneumatic tires, and also with smooth metal rolls. The first passes are made with light rollers, and subsequent - heavier with increase pressure in the tires. Embankments more than 20 cm thick must be compacted in layers.

During soil compaction every subsequent pass of the roller should overlap the previous. Compacting continues until on the surface of soil there remain only the impressions of the tread of the pneumatic tires of the roller. The number of passes of rollers along one track depends upon the type of soil, its state, weight of the roller, pressure in tires and is taken from two to eight. The motion of rollers during compacting can be accomplished in any direction with respect to the axis of the RW, however the last two or three tracks should be accomplished along the axis of the RW.

With insufficient moisture of the soil and the necessity for urgently bringing the flying field to a state suitable for operation, artificial moistening of the soils should be accomplished

before compacting with the bringing of their moisture to a state close to optimum.

After performing work on the strengthening of soils we take check measurements of its strength and make a conclusion about the suitability of the flying strip for operation by some types of aircraft.

#### § 71. OPERATING REGULATIONS OF THE SOD COVERING OF THE FLYING FIELD

Care of the sod covering of the flying field includes soil compaction; raking of sod covering; mowing of grasses; the feeding of grass with mineral fertilizer; artificial watering of grass; rodent control.

For care of the sod covering there are used tractors on pneumatic tires, and also caterpillar tractors, whose tracks are equipped with rubber or wood plates.

Soil compaction is accomplished for strengthening the soil and intensification or tillering of the lower herbaceous grasses. When high herbage exists on the flying field, before compacting it is necessary to mow the grass, since when compacting the surface with unmown herbage the normal growth of grass is disturbed and its subsequent mowing is impeded.

The sod covering is raked for the improvement of the air conditions of the root system of grassy plants, and also for the removal of withered and dry residue of vegetation. Raking is done in the spring by "zigzag" harrows or by tractor (horse) rakes in one-two tracks (along and across the strip).

The grass is mowed by tractor or horse mowers, when the height of grass reaches 25-30 cm. The height of grass, left at the root, should be not below 8-10 cm. The frequent and low

mowing of grass during the early period of growth weakens the plants and can lead to their death. The mowing periods of grass are established in each case separately depending on the height and thickness of herbage, speed of growth of grass and local soil-climate conditions. The last mowing of grass is accomplished three or four weeks before the onset of stable cold weather in the given area. The grass should be mowed on the entire flying field, since on some sections the grass perishes, is choked in by weeds, which are subsequently spread over the entire area of the flying field. Weeds are destroyed by the mowing of herbage before their mass seeding. Coarse-stemmed weeds are destroyed by undercutting them with a sharp picker. The mowed grass is gathered by tractor or horse-drawn rakes and immediately removed from the territory of the flying field.

One of the main measures of care of the sod covering is the dressing of grass and sod formers with mineral fertilizers. The grass is dressed, as a rule, with nitrogen, phosphoric and potassium fertilizers. It is necessary to perform dressing in two stages: in the spring before the beginning of the growth of grass, and in the summer after the removal of the first cutting. In areas with an insufficient amount of precipitation during the summer-autumn period dressing should be accomplished only in the early spring.

Depending on the type of ground, its fertility and the state of herbage the norms of introduction of fertilizers are different. In performing dressings it is necessary to be guided by the approximate norms of introduction of fertilizers: nitrogen 2-3 centner/ha; phosphoric 2.5-4 centner/ha; potassium 1.5-2 centner/ha.

On fertile soils the quantity of fertilizer is decreased, while on infertile it is increased within the indicated norms.

Mineral fertilizers before introduction into the ground must be ground and sifted. The mineral fertilizers which acidify the ground (ammonium sulphate, superphosphate on acid soils), before introduction into the ground are neutralized by the addition of limestone at a rate of 70-100 kg per 100 kg of fertilizer.

It is better to perform the spring dressing of grass after its mowing. For uniform distribution over the flying field surface mineral fertilizers are scattered by fertilizer sowers, which are preliminarily set to the necessary norm of sowing. In summer, especially with the absence of atmospheric precipitation, it is recommended to introduce mineral fertilizers in liquid state. The solution of mineral fertilizers for spreading must be prepared at a rate of 6.5-7.0 kg of ammonium sulphate, 5 kg of superphosphate and 2.5 kg of potassium sulfate for 1 m<sup>3</sup> water. The spreading is accomplished by street-sprinkling machines: norm 1.5-2.0 liters of the solution per 1 m<sup>2</sup> of flying field.

Besides the introduction of mineral fertilizers, it is advantageous to haul in the soil of the sod covering, which involves the sprinkling of a thin layer (2-3 mm thick) of good topsoil on its surface. This facilitates the softening of the effect of adverse factors (droughts, frosts), intensified tillering of grass, the formation of a dense grassy covering. It should be performed not less than 2 times during the vegetative season.

When alkaline spots exist on the sod covering, at these places gypsum should be introduced in the amount of 0.5-1 kg per 1 m<sup>2</sup>, and on acid soils - lime at the rate of 0.3-0.5 kg per 1 m<sup>2</sup> depending on the degree of acidity of the soil.

For dealing with rodents, which cause great harm to the sod covering, on flying fields it is most advantageous to use chemical methods. For the destruction of large rodents living in deep burrows (gophers, hamsters, moles), it is recommended to use



suffocating substances, for example, chloropicrin, while for small mouse-like rodents (house or burrowing mouse, field mouse, voles, small sand rats and others) - bait from bread (cakes) and grain poisoned with sodium arsenite or white arsenic.

For preparation the bread or cake bait is cut into small pieces (not larger than a hazelnut) and dipped in a sieve for 0.5-1 min into an earlier prepared solution (1 part of sodium arsenite per 30 parts of warm water). Then the sieve is raised, left to drain off the excess solution back into the container, the bread is removed and distributed in some container along the burrows. Into each burrow is placed one small piece of the poisoned bread. It is recommended to add sugar or syrup to the bait. Grain for the preparation of bait is dipped into a more concentrated solution of sodium arsenite (1:20) for 24 h with mixing every 3-4 h. With the use of white arsenic as poison it is dissolved in hot water in the same proportions as sodium arsenite.

It is better to begin dealing with mouse-like rodents in the early spring immediately after the removal of snow and to continue until the appearance of dense vegetation. In the autumn after the withering of vegetation the works can be renewed and performed until the falling of snow. It is necessary to use poisons with large precaution and only under the guidance of specialists, who well know poisonous chemical agents and know how to render the necessary first aid to those injured from weed-killers.

## § 72. MACHINES FOR MAINTENANCE AND REPAIR OF UNPAVED FLYING STRIPS

For the summer maintenance of airfields we use digging, planing, soil-compacting and machines for the care of unpaved flying strips and sod covering.

As digging machines during the summer maintenance of airfields there are used D-535 bulldozers (Fig. 97), loader dozer D-442 (Fig. 98), scrapers and excavators. Bulldozers are intended for: the cutting and movement of soil to a distance up to 50-70 m; filling of trenches, ditches and large ravines; the rough smoothing of mounded soil. Loader dozers, furthermore, are used for accomplishing loading and unloading operations.

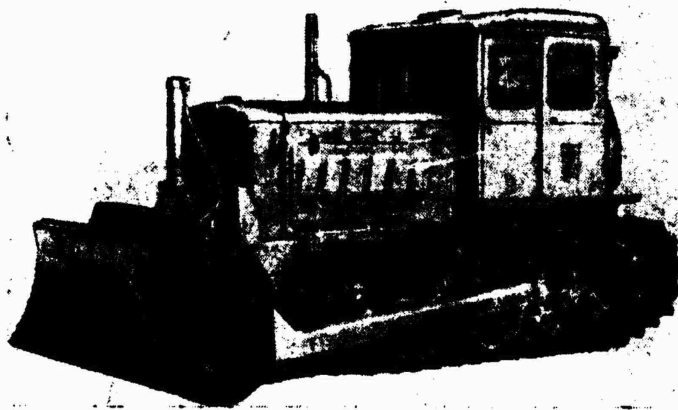


Fig. 97. D-535 bulldozer.

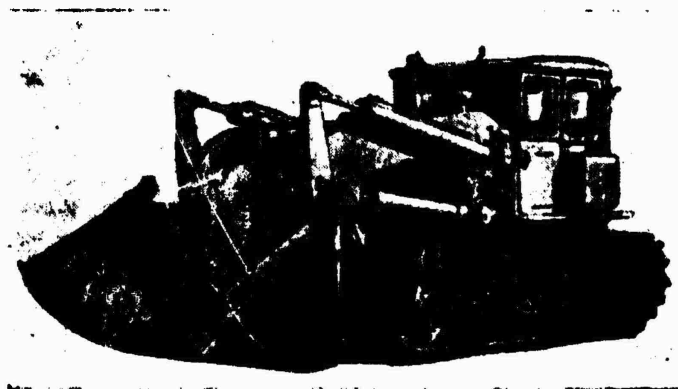


Fig. 98. Loader dozer D-442.

Scrapers are intended for layer development, movement and pouring of soil during the accomplishment of the following types of earth works: the removal and restoration of the plant layer

of soil; the development of excavations and the pouring of embankments. Scrapers D-354 and D-541 (Fig. 99) used on airfields are trailers to the DT-54 tractor.

Excavators are intended for the development and movement of earth masses and the mechanization of loading and unloading operations. The excavator E-153 (Fig. 100) used on airfields is a self-propelled machine mounted on the pneumatic-tire tractor MTZ-2 "Belarus'" and has additional bulldozer equipment.

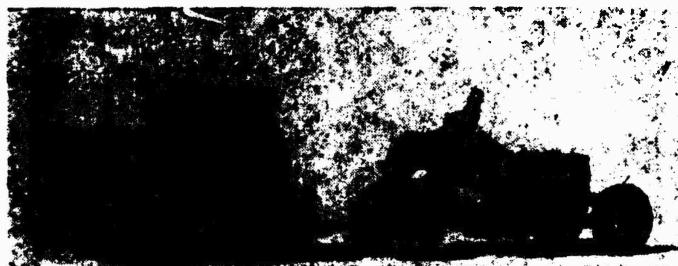


Fig. 99. Scraper D-541.

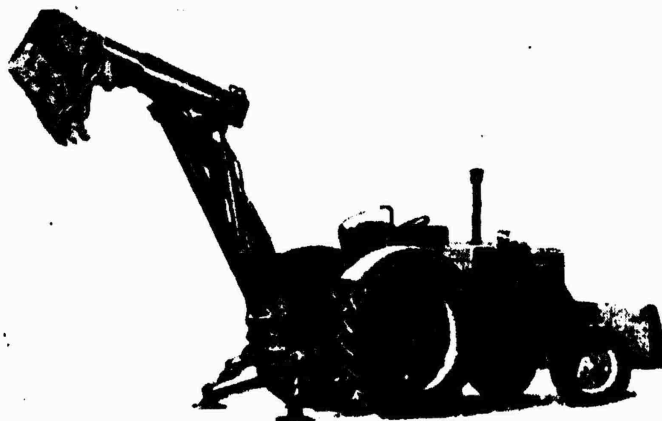


Fig. 100. Excavator E-153.

As planing machines during the summer maintenance of airfields there are used motorized road graders (both without lengthening attachments and with attachments), trailer graders and trailer long-base planers. Planing machines are designed for the planing

of unpaved flying strips and dirt roads; the movement and smoothing of soil; filling small trenches, ditches, wheel tracks and gullies.

For increase of the capacity and improvement of the quality of planing the motorized road graders with hydraulic or pneumatic control drive are equipped with special lengthening attachments (Fig. 101).

Long-base planers (Fig. 102) are used, as a rule, during the final (finish) planing of the unpaved surface.

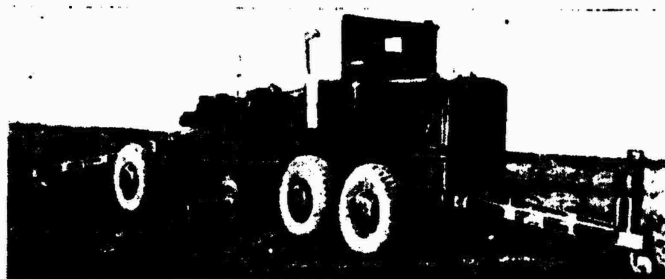


Fig. 101. Motorized road grader with lengthening attachments.



Fig. 102. Long-base planer.

The motorized road grader D-598 used on airfields is shown on Fig. 103.

As soil-compacting machines during the summer maintenance of airfields there are used trailer pneumatic rubber rollers D-219

and D-326. Pneumatic rubber rollers are designed for the layered compacting of freshly poured soils during the erection of embankments, the shaping of roads, and also for the soil compaction during the repair and operational care of the unpaved flying strip.



Fig. 103. Motorized road grader D-598.

For the care of unpaved takeoff areas and sod covering there are used combined KPM-2 and KPM-64 soil-watering, and also agricultural machines and mechanisms.

The soil-watering equipment of KPM-2 and KPM-64 machines is intended for the watering of dirt strips and takeoff areas, green plants and grass. The soil-watering equipment can also be used for the washing of artificial surfaces and an auxiliary means when quenching fires. The KPM-2 and KPM-64 machines with soil-watering equipment used on airfields are shown on Figs. 104 and 105.

Agricultural machines and mechanisms are intended for the creation and care of the sod cover on the dirt part of the flying field of airfields.



Fig. 104. Soil-watering machine KPM-2.

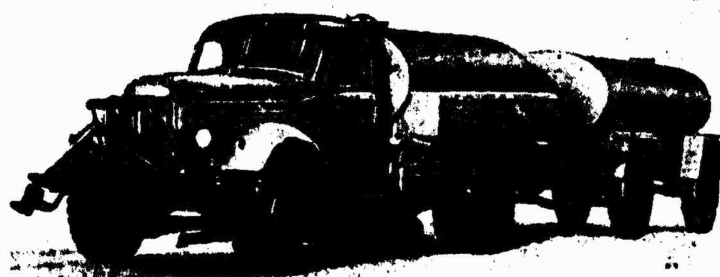


Fig. 105. Soil-watering machine KPM-64.

## CHAPTER XVII

### THE MAINTENANCE AND REPAIR OF RIGID COVERINGS

#### § 73. MAINTENANCE AND REPAIR REGULATIONS

The maintenance and repair of the rigid coverings of RW, RD and MS of aircraft are accomplished for the provision of constant readiness of the airfield for flights; the preservation of the coverings from premature wear and damage from the effects of moving aircraft loads and natural factors; increase of the service life of coverings.

The maintenance of coverings includes their inspection and care. The maintenance involves the cleaning of coverings from contamination, dust, pieces of broken concrete, wire, etc., the detection and removal of small defects. The maintenance operations of the coverings are performed during the entire year. The coverings are inspected daily before the beginning of flights and after their termination. During the inspection the defects of coverings are revealed. Special attention is paid to the good condition of grids, rain-gully wells, over which aircraft motion is possible. The discovered defects are recorded in a special log and are removed in the interruptions between flights.

The repair of coverings involves the elimination of the defects of individual slabs of small sections and even whole areas of coverings. Depending on the volume of works we distinguish routine and major repairs.

Routine maintenance consists of the prevention and urgent removal of defects of the individual slabs or small sections of coverings. Routine maintenance includes: the replacement of individual sections of coverings of cast in-situ concrete and reinforced concrete or precast sectional slabs with straightening of the base in the volume, which does not exceed 1% of the entire area of the covering of the airfield; the raising of individual plates sagged up to 3 cm by means of forcing a solution under the slab; the elimination of sags of individual slabs by placing an asphalt-concrete mat on them and other materials, treated with binding agent; the sealing and repair of surface and through cracks, pits, potholes, broken corners, the edges and peelings of the cement crust (flaking) of the slabs, the repair and filling of damaged joints with mastics; the repair of defects on precast reinforced-concrete slabs; the straightening of individual border stones of MS and ramps. Routine maintenance is accomplished routinely during one year in the interruptions between the flights of aircraft.

Major repair includes the works on the repair of coverings on large areas. Among these are: the shifting of individual deformed sections of coverings or the replacement of individual slabs of cast in-situ concrete, ferroconcrete, reinforced concrete or precast sectional ferroconcrete with correction of the base in the volume up to 25% of the total area of the airfield coverings; the levelling of the sagged covering in the volume more than 10% of the total area of the airfield by means of the placement of asphalt-concrete mixture or other materials treated with binding agent; the levelling and reinforcement of cement-concrete coverings of RW, RD, MS, ramps, danger areas by means



of laying a new layer of asphalt concrete, precast reinforced-concrete slabs and others; the elimination of surface deformations of the coverings - flaking, pits, potholes, broken corners and the edges of slabs on sections with area more than 25% of the total area of the airfield coverings.

When determining the periods between major repair as the basic criterion we take the state of coverings, which greatly depends upon the intensity of operation of the airfield by aircraft. The tentative service life of coverings before major repair can be determined by proceeding from the permissible quantity and the prescribed intensity of takeoff and landing operations per annum.

The permissible quantity of takeoff and landing operations depending on the construction of covering and the type of aircraft is determined by formula

$$N = \frac{\alpha \beta k}{b n} \quad (83)$$

where  $\alpha$  - coefficient considering the distribution of aircraft movement during takeoffs and landings along the entire width of the RW (if 90% of all aircraft takeoffs and landings occur on the middle part of the width, and 10% - on the edge sections, which is the most characteristic for the operation of airfields,  $\alpha = 1.1$ );

$\beta$  - coefficient considering the influence of the quality of reference points of the aircraft (when there are two main struts  $\beta = 0.5$ );

$B$  - runway width;

$k$  - coefficient determining the permissible quantity of passes of the aircraft wheels along one track (for single-layer concrete coverings with pin-type connections in compression and expansion joints  $k = 5000-7000$ ; the same, with reinforcement of the edge sections of slabs of through joints  $k = 4000-4500$ );

$b$  - width of the track of aircraft pneumatic tires;

$n$  - the number of wheels on one strut of the aircraft landing gear.

For computation of the period of repair of the coverings it is necessary to divide the permissible quantity of takeoff and landing operations by the annual intensity of airport operation.

Major repair of rigid coverings is performed periodically: for reinforced-concrete cast in-situ every 15-20 years; for cement-concrete cast in-situ every 10-14 years, for precast sectional reinforced-concrete every 5-8 years. During major repair the flight work at the airfield is ceased.

#### § 74. THE TYPES OF DEFORMATIONS AND FAILURES, THE REASONS FOR THEIR APPEARANCE AND PREVENTIVE MAINTENANCE

The deformations and failures of rigid coverings can be related to one of the following groups: failures caused by the effect of aircraft loads; temperature failures; surface failures from the effect of jet engines and atmospheric factors; failures connected with phenomenon of swell-formation; defects of a production character.

The most characteristic failures of concrete coverings, caused by aircraft, are the breaks of the corners of slabs, the chips of concrete in transverse and groove joints, longitudinal and transverse cracks (Fig. 106). The greatest deformations of slabs are observed at the beginning and the end of runways, on taxiways, i.e., on the most loaded sections of the coverings.



Fig. 106. Deformations of concrete covering.

In a number of cases in concrete coverings even before the beginning of operation of the airfield there appear longitudinal or transverse through cracks, caused by temperature stresses. From Table 65 it follows that with decrease in size (from  $7 \times 7$  m to  $5 \times 4$  or to  $4 \times 3.5$  m) the quantity of plates with defects was considerably reduced. The operating experience of the airfield coverings showed that in the course of time there occurs the surface failure of concrete, so-called "flaking" to a depth from 2 to 6 cm, with this the surface of the covering becomes uneven, due to which for the aircraft during motion there appears vibration, and the sharp edges of peelings cause cuts and punctures of tires. "Flaking" in lenticular form prevents water runoff from coverings, which leads to the icing up of coverings in the winter period and contributes to their further failure.

Table 65

Thickness of slabs, cm	Size of slabs, m	Quantity of examined plates, pieces.	Quantity of plates with through cracks	
			Pieces	%
20	$7 \times 7$	27,806	3,845	13.83
20	$5 \times 4$	32,117	177	0.55
20	$4 \times 3.5$	13,034	17	0.14

The breaks of similar character in lenticular form of irregular shape with cross section from 3 to 13 cm, depth 1-2 cm are more often encountered on airfields being operated by jet aircraft. The thermal effect of a jet engine on the covering in the surface layer of slabs creates sharp temperature differences, which cause dangerous temperature stresses in this layer, which combined with the high-speed effect of the flow of exhaust gases of a jet engine create conditions for the surface damage of slabs of the concrete covering.

The distribution of slabs with surface failure according to the elements of coverings (in %) to the total amount of plates is the following:

GMS (group MS)	34.7
Alert aprons	13.3
RD main	6.8
RD connecting	11.1
RW (on the average)	3.0

Analysis of these data shows that substantial deformations of the surface layer are observed on sections where aircraft movement occurs at low speed, and on aircraft parking places, i.e., where the duration and repetition of the effect of the flow of exhaust gases from jet engines are quite great.

At airfields, constructed in areas where the swelling of the ground bases can occur, damages of the coverings are encountered which can encompass comparatively large sections (Fig. 107). The quantity of slabs with through cracks in this case will be able to reach 20-27% of the total amount of slabs. Observations show that on some coverings as a result of the poor quality of work surface defects are formed in the form of waves in longitudinal direction, unevenness near joints, soulders and others.

Shoulders in the joints of slabs are predominant with height up to 5 mm, and on separate sections they reach 15-20 mm (Fig. 108). On the surface of concrete coverings there sometimes appear shrinkage cracks, allowed because of deficiency in the care of the hardening concrete. These cracks in the course of time change into through and can be the cause of failures of coverings. The formation of through cracks was detected after 3-4 years of operation of airfields. The considered deformations and failures of coverings appear for two basic reasons: from the repeated actions of aircraft loads and from insufficient consideration of

climate, atmospheric and hydrogeological factors when developing the technical project and designing the coverings, the low quality of work during their construction.

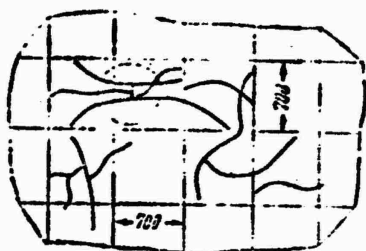
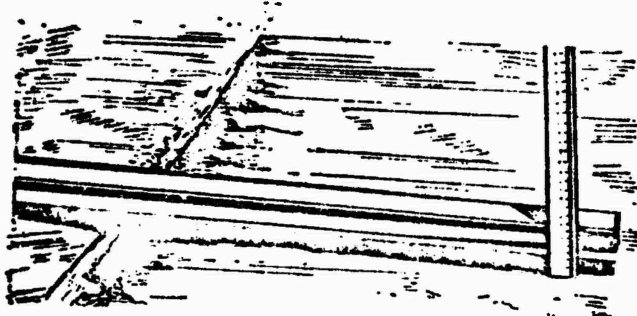


Fig. 107. The failure of a covering from the swelling of the ground base (in the circle the rise of the slabs of the covering is up to 15 cm).

Fig. 108. Shoulder in the joint of rectangular concrete slabs.



For the prevention of premature wear of the upper surface of the concrete coverings from operational aircraft effects, it is necessary to pay special attention to the systematic and thorough maintenance and repair of coverings.

#### § 75. METHODS AND MACHINES FOR THE CLEANING OF COVERINGS

The sources of dust, sand and contamination on rigid coatings are: the products of wear of the fillers of joints as a result of their abrasion and crumbling; the dust, being carried by the wind and by the jets of the operating engines of aircraft on the coating from adjacent sections of the flying field; contamination,

being dragged away by the wheels of automobiles from dirt roads and from the flying field.

The presence of dust, sand, contamination and other foreign objects (pieces of concrete, crushed stone, metal objects) considerably complicates takeoff and landing from the coverings. Dust restricts the visibility during aircraft landings and decreases the throughput capacity of the airfield. Contamination makes the conditions of movement and braking of the aircraft worse. Sand, dust, foreign objects, getting into the engines and other units, considerably increase aircraft wear. Therefore on airfields there should be organized constant care and cleaning of the surface of rigid coverings. In the spring after the thawing of the snow cover we thoroughly inspect and check the state of the joints between slabs. Damages in the joints should be eliminated 10-15 days after the onset of warm weather. The dislodged and crumbled filling of the joints is completely restored. For this the joints are thoroughly cleansed of sand, fragments of crushed stone, pieces of filler and contamination by iron hooks and stiff brushes to a depth up to 5 cm. The cleaned and dried seam is filled to the top with hot bitumen or with a mixture of tar with mineral powder in proportion 1:1.5 and is sprinkled with dry sand.

Under summer conditions we destroy the vegetation in the joints between slabs. For this the joints are wet with special solutions (at a rate of 0.5 l per 2 linear meters) from funnels or hoses connected with mobile containers. The solution is prepared in barrels or buckets of the following composition (norms per 1 liter):

Thiocyanate of sodium salt	80 g
Thiocyanate of aluminum salt	100 g
Potassium chlorate (Berthollet's salt)	150 g
Magnesium chlorate	100 g

With the absence of the indicated reagents the vegetation in the joints is removed by spades. The filling of the joints also should be thoroughly inspected and restored in the autumn three or four weeks before the onset of rains and frosts.

The cleaning of rigid coverings from dust, sand and contamination is accomplished by sweeping, watering and washing. For the watering of coverings we use watering machines, which evenly spray water according to norm 0.2-0.5 liters per 1 m<sup>2</sup> of covering. The washing machines wash off dust and contamination by a strong flat stream of water with water consumption 1 liter per 1 m<sup>2</sup>. Usually the watering and washing of coverings are accomplished by combined street-sprinkling machines, which are equipped with street-sprinkling devices. For the acceleration of works watering is performed by columns of street-sprinkling machines, which move with offset one after another.

For the removal of dust, sand and foreign objects it is advantageous to use vacuum-collecting machines. They are equipped with suction devices, which suck foreign objects from coverings into special settling chambers. After their filling the chambers are cleaned.

For the pulling of fine metal parts from the coverings, which cause damage to tires, outside the boundary we use trucks, under the chassis of which are suspended three powerful electromagnets at a height of 10-15 cm above the covering. During the motion of the truck with speed up to 20 km/h the magnets lift up iron objects weighing 1 kg. For the release of magnets from the captured objects on special platforms the current is turned off.

§ 76. METHODS, MATERIALS AND MACHINES  
FOR THE REPAIR OF JOINTS, CRACKS  
BREAKS, PITS, PEELING AND SAGS

For the repair of rigid coverings we use bituminous materials and asphalt (sand and fine-grained); cement mortars with chemical additions and epoxy resins.

The repair of coverings with bituminous materials and with asphalt is performed on the sections which have surface peeling or with the exposure of large filler, pits, breaks of edges and corners of slabs, shrinkage and through longitudinal and transverse cracks. The coverings must be repaired in dry and warm weather. The main purpose of repair is the creation of waterproofing and the preservation of the covering from further damage.

Of vital importance for increase in the bearing capacity of rigid coverings is the elimination of cracks. The sealing of cracks is accomplished differently, depending on their width, since solutions of different consistency do not penetrate to the entire depth in all cracks. All cracks (both through and shrinkage) with respect to the penetration of solutions are subdivided (according to width) into three groups: cracks up to 2 mm; from 2 to 6 mm; more than 6 mm.

Materials for repair and the methods of their use are selected for each crack so as to provide the deepest and most durable waterproof sealing of cracks, to use sufficiently inexpensive and widespread materials and to complete the work with simple means. During the sealing of cracks and breaks it is necessary to thoroughly observe the below-recommended compositions and methods of production of the materials and technology of the performance of work.

Before the repair the surface of the covering should be thoroughly prepared: there should be removed the damages and



peeled off particles of concrete, grease spots, bitumen, etc., in order to achieve the best adhesion of the material of the repair layer with bitumen. Particles of concrete and dust are removed by wire brushes, blasting with compressed air and flushing with water. The places of breaking off of the edges of slabs and pot-holes 5 cm in depth and more are given rectangular shape on the cross section or conical with broadening downward, and then cleaned of dust and washed by water. The work during the creation of preliminary layers of priming should also be thorough. In all cases on the surface of slabs the layer of bituminous materials (solutions or mastics) should be minimum (not more than 0.3 mm), otherwise their separation and the deterioration of the aircraft braking conditions are possible.

The quality of repair of airfield coverings with bitumen and asphalt much depends upon the quality of the materials used. They should be sufficiently durable, reliably joined with the surface being repaired, be frostproof and waterproof, be applied to the covering with a thin layer, fill cracks and penetrate the pores of concrete.

For the sealing of joints, cracks, pits, breaks and the repair of coverings with peeling the following materials are used:

Bitumen. For the sealing of cracks and breaks we use bitumen of brands BND-60/90 and BND-90/130. Bitumen BND-60/90 is used for the preparation of bitumen solutions in gasoline, and BND-90/130 - for the preparation of bitumastic and asphalt.

Mastics "Izol" of brand I-1 and I-2, and in the case of their absence mastic M-1. The composition of mastics is given in Table 66.

Table 66

Brand of mastic	Materials entering the composition of mastics, % by weight						
	Rubber chips	Bitumen	High-melting alloy	Coumarone resin	Rosin	7th type of asbestos	Fine sand
I-1	19.0	60.0	-	4.0	2.0	15.0	-
I-2	20.0	75.0	-	5.0	-	-	-
M-1	-	24.0	56	-	-	6.0	14

- Notes.
1. The rubber chips should be not coarser than 2 mm.
  2. Asbestos chips should correspond to GOST 7-51.
  3. High-melting alloy is an alloy of shugur bitumen and sadkinskiy asphalt. The softening temperature of this alloy (according to "ball and ring" instrument) is 105-120°C. The alloy is manufactured at the shugur bitumen plant.

Asphalt. Its composition: bitumastic - 20%, bitumen BND-90/130 - 15%, crushed stone grit and sand (proportion 1:1) - 65%.

The coverings with bitumen and asphalt are repaired depending on the type of damage.

a) Sections with surface damage. The surface of the covering is thoroughly cleaned and dried. Then we prime the surface with BND-60/90 bitumen, diluted in kerosene or gasoline in 1:1 proportion. To the primed surface we apply a layer of BND-90/130 bitumen 3-5 cm thick. On top it is sprinkled with grit with grain size not more than 9 mm and compacted by rollers.

b) Sections with peeling of concrete throughout the depth. The surface of the covering being repaired is thoroughly cleaned and dried, after which it is primed with a solution of BND-60/90 bitumen in kerosene or gasoline in 1:1 proportion. Then we place a layer of hot fine-grained asphalt, sprinkle it with grit 2-3 mm in size and pack with a roller.

c) Sealing of cracks up to 2 mm wide. Before the sealing of cracks the slabs are cleaned, and all cracks on its surface are thoroughly blasted with compressed air. Then with a paint spray gun or brushes on the track of the single crack we apply a 40% solution of BND-60/90 bitumen in gasoline; such painting should be done 3 times. Repeated painting is possible only after the drying of bitumen (in 30-60 min). Then for the final sealing of the crack it is necessary to apply one time a 50% solution of BND-60/90 bitumen, diluted in gasoline. If on the slab there are sections with a considerable quantity of cracks, then the solution is applied over the entire area of these sections. The method of application of the solution is the same as for single cracks.

d) Sealing of cracks from 2 to 6 mm wide. Cracks of such width must be preliminarily separated with the aid of an electric drill or chisel into grooves with rectangular cross sections not more than 8-10 mm wide, 30-35 mm deep and blown with compressed air. The separated grooves must be painted 2 times with a 50% solution of BND-60/90 bitumen in gasoline. It is possible to paint repeatedly only after the drying of primer. Bitumen solutions are applied by brushes or a paint spray gun. After the drying of bitumen solution the cracks should be filled flush with "Izol" or M-1 bitumastic with the aid of a pourer of joints or funnels. When filling the cracks with bitumastic it is necessary to observe the following: the temperature of mastic should be not below 170°C and not higher than 220°C; do not allow the cooling

of mastic and continuously mix the mastic in the pourer or funnels. The excess mastic on the surface of slabs after its complete cooling should be cut off with a heated shovel.

e) Sealing of cracks more than 6 mm wide. Before sealing the cracks it is necessary to clean the surface of the slab and blow the cracks with compressed air; then paint 2 times with a 50% solution of BND-60/90 bitumen in gasoline with a paint spray gun or brushes over a dry surface. After the drying of bitumen solution the cracks should be filled to the top with bitumastic. The mastic, protruding above the surface of the slab, after cooling must be cut off with a heated shovel. The method of sealing of fissures is no different from that expounded above.

The repair of joints. Joints are cleaned of contamination, blown with compressed air and painted with a solution of BND-60/90 bitumen in gasoline or kerosene in 1:1 proportion. After the drying of the joint priming we pour "Izol" or M-1 mastic with the aid of D-344 pourer, funnels with capacity 6-8 liters (Fig. 109) or portable tanks (Fig. 110).

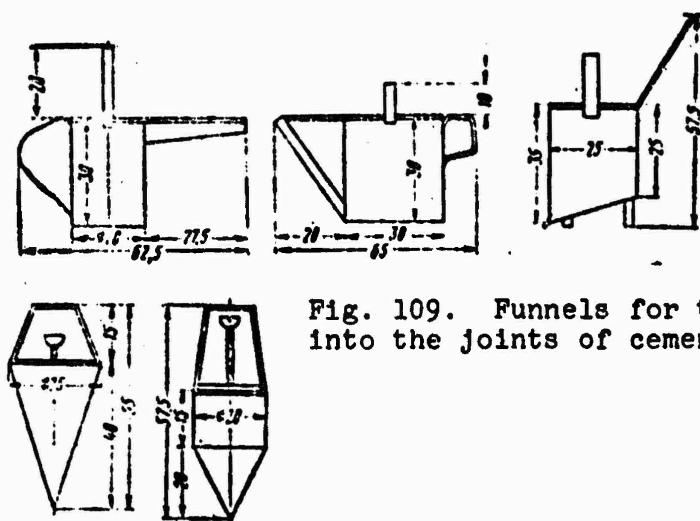
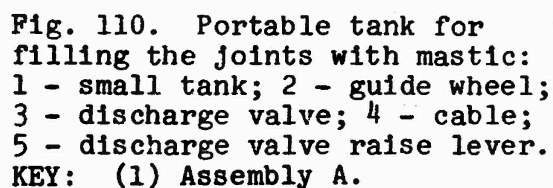


Fig. 109. Funnels for the pouring of mastic into the joints of cement-concrete coverings.



Repair of coverings with sand-cement solutions and with ordinary concrete, as a rule, is accomplished on sections where the gassing of engines and the servicing of aircraft with fuel and lubricants occur. The use of cement-sand solution and concrete is allowed on the remaining sections of coverings.

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moist concrete there is applied a bonding layer from cement mortar 1:1 or cement test and is ground by scrubbers until a layer 1.5-3.0 mm thick is obtained. To the moist bonding layer we apply a base layer of sand-cement solution 1-2 cm thick, level and pack with vibrator racks or plaster graters. After packing it is necessary to provide for care of the layer of solution just as after freshly poured concrete (filling with a layer of moist sand). Recently for improvement of the cohesion of sand-cement solution we pour on epoxy glue, which is applied to the prepared surface of old concrete by brushes in the form of a thin layer. The consumption of glue in this case should not exceed 0.3-0.5 kg for 1 m<sup>2</sup> of treated surface.

With the depth of the damaged layer more than 5 cm the coverings are repaired by concrete with filler, the largest grain size of which does not exceed 2/3 the thickness of the built-up layer. Concrete in this case is placed on a layer of cement test, leveled and packed by an area vibrator.

With the depth of the damaged layer more than 10 cm we preliminarily cut out the damaged concrete by concrete breakers or wedges. We further build up the new concrete. The strength of the placed concrete should correspond to the strength of the covering being repaired. The completely destroyed separate slabs and sections are removed from the covering, the base is restored and the new slabs are concreted with restoration of seams and butt joints. The prestressed sections, as a rule, are replaced by reinforced-concrete slabs. The defective places of joints and the broken reinforcement metal on precast reinforced-concrete slabs are removed with the aid of welding.

For the elimination of sags of durable and nonworn slabs they are lifted with a jack with the aid of hooks and into holes drilled in the slabs we force a mixture of sand with cement for complete filling of the formed cavity.

The successes of the chemical industry make it possible to use cement mortars with chemical additions and epoxy resins for the repair of coverings. GosNII GA, GPI and NII GA "Aeroprojekt" together with the Institute of Physical Chemistry of Academy of Sciences of the USSR developed a method of the repair of rigid coverings with the aid of cement mortar and special colloidal glue, which provides reliable cohesion of the mortar with the existing concrete coverings. Colloidal glue is prepared from portland cement, ground to a specific surface not lower than  $5000 \text{ cm}^2/\text{g}$ . As additions we use fine-grained sand in the amount up to 40% of the portland cement, plasticizers in the form of sulfate-alcohol residue and hardener - calcium chloride. The mixture is mixed with water not less than two hours. As repair material there is used brand 500 mortar, prepared on finely ground cement. The repair technology of concrete coverings with damaged top layer is such: to the covering being repaired immediately before the packing of cement mortar there is applied a layer of glue 1.5 mm thick; on the concrete surface prepared in this way we place mortar with a layer from 0.5 to 5 cm, which is packed by a vibrating platform in one-two passes. The coverings are repaired with the aid of the specially created airport road-mending machine D-694, consisting of three units: mixing device, glue preparer and placer.

For the repair of a concrete surface with flaking to a depth of 0.3-3.0 mm, and also with pits and ruts with a depth of 4-7 cm according to the recommendations of L. I. Goretskiy and A. V. Afonskiy we use solutions with chemical additives. For the build-up of layers of damage from 2 to 5 cm we use cement mortar with the additions of latex, polyvinyl acetate, salts of calcium and sodium chloride together with sulfate-alcohol residue, and also a solution of silicone oil. It is recommended to introduce chemical additions in the amount of 1.5-3% in the conversion to dry weight from the weight of cement.

The surface treatment of the coverings, which have insignificant flaking, is performed by the impregnation of magnesium 2 times with fluosilicate salts with intervals 10-20 h and 20% solution with interval 1-2 h. The coverings are repaired in the first half of the summer so that before the beginning of winter normal conditions of hardening would be provided.

For the repair of coverings, subjected to flaking, and also for the sealing of ruts, cracks, pits, seams and destroyed edges we use epoxy resins EP-5 and ED-6 with the appropriate hardners. Under the action of hardener the epoxy resins change from liquid state into solid. The concrete coverings repaired by epoxy resins possess high strength and waterproof properties. The surface of the covering being repaired should be preliminarily cleaned, washed, dried and painted with a solution of "Izol" mastic in gasoline. After this on the surface we apply epoxy resin and distribute it with a trowel or shovel. The surface is finally finished by leveling with a beam, trowelling and smoothing.

The filling of cracks and seams with epoxy solutions is performed in two stages: the first with solutions of smaller concentration, in order to provide for sufficient filling of the voids, and then with the most concentrated, with which it is necessary to completely fill the seams and cracks. Then the surface of concrete near them is smeared with the same epoxy solution and fine dry sand is put on.

#### § 77. THE ORGANIZATION OF REPAIR OPERATIONS, QUALITY CONTROL ACCEPTANCE. SAFETY ENGINEERING

The airfield service which ensures the constant readiness of the airfield for flights, keeps an account of the technical state of artificial coverings and an account of takeoff and landing operations on the airfields, accomplishes the planning of



operations on the maintenance and routine repairs of all constructions of the airfield, including the artificial coverings.

As the basic documents for the organization and planning of repair operations there are the reports of defects, the charts and plans of operations and the schedule chart of the accomplishing of operations. The reports are compiled yearly by a board of specialists and they contain a description of the defects and faults of artificial coverings. On the basis of these reports there is compiled the plan chart, which contains the list and volume of repair work, its cost. On the basis of the approved plan there is compiled the schedule chart of the accomplishing of repair work. The work on the maintenance and routine repairs of coverings is performed during the entire year.

For the acceptance of the completed repair work there is designated a board, taking measurements of the completed work and in conformity with their approved plan, determines their quality. The board compiles a report, in which there is indicated the name, the quantity, the quality and the cost of the repair of coverings. The report is approved by the airport manager and is stored in the files of the airfield service.

For quality control there are conducted control rollings of the repaired sections by mobile units, simulating the strut of an aircraft of calculated weight. Simultaneously with this we check the laboratory analyses of repair materials, the actual strength of cement mortars and concrete. The revealed data should not be different from the repair work accepted in the plan.

All work on the maintenance and repair of rigid coverings with the use of bituminous materials, chemical additions and epoxy resins should provide safety measures and safety engineering. For this it is necessary to acquaint the workers with the technology of preparation of bituminous mixtures, solutions, with chemical

additions and epoxy resins. The workers should be taught the handling of combustibles, and should also have overalls. During the preparation of diluted bitumen it is necessary to observe the following regulations: it is prohibited to smoke and start a fire; it is necessary to introduce the gasoline into bitumen away from the place of the heating of bitumen; the temperature of bitumen during the introduction of gasoline into it should be not higher than 80-85°C. It is mandatory to equip boilers with metal covers.

## CHAPTER XVIII

### THE MAINTENANCE AND REPAIR OF NONRIGID COVERINGS

#### § 78. MAINTENANCE REGULATIONS

The maintenance of nonrigid coverings consists of their inspection and care. The inspection is reduced to the detection and elimination of small defects, the removal of dust, contamination and others. The residue of contamination, especially clay soils, highly lowers the coefficient of adhesion and therefore is a threat to aircraft motion. The coverings are cleaned of dust and contamination by mechanical brushes with mandatory removal away from the coverings.

In a dry period for dust removal the coverings are wet with water. On hot days under the action of motion and solar rays the binding agent can come to the surface of the covering. The places of softening, on which the impressions of the pneumatic tires of aircraft remain, are sprinkled with grit or coarse-grained sand. The sections which have damages are also revealed. On such sections aircraft motion should be limited and repair work rapidly performed. Upon the completion of repair the repaired sections are thoroughly inspected and accepted for operation.

During the care of improved and simplified coverings attention is given to the maintaining of evenness and gradients,

which facilitate the rapid runoff of precipitation from the surface of the coverings. In the warm period the simplified coverings are periodically packed by pneumatic rubber rollers. This is also done during the period of drying out of the soil after rains and the bad road period.

One of the primary tasks of care is the provision for watertightness of coverings, since water leads to their intense damage. After rains on the covering there can occur pitting of the layer of treatment, a network of fine cracks and moist spots can appear. Atmospheric water can penetrate the body of coverings and in the future destroy them.

For the elimination of these defects the sections of coverings in dry weather are cleaned and then covered with hot bitumen. After this crushed stone is melted into the bitumen. The atmospheric water, accumulated in low places, must be removed from the covering.

#### § 79. THE TYPES OF DAMAGES, THE REASONS FOR THEIR APPEARANCE AND PREVENTIVE MAINTENANCE

With the correctly selected mixture composition, high quality of materials and construction work the nonrigid coverings possess high water-resistance, strength, freedom from dust, elasticity and allow the intense operation of aircraft. The breakdown of the technology of construction, shortcomings in the operational maintenance, poor draining lead to the formation of damages of nonrigid coverings. The most characteristic damages of nonrigid coverings are cracks, ruts, dents, tracks, upheavals and washouts, waves, peeling and wear.

On the coverings occur transverse, longitudinal, oblique cracks and cracks in the form of a fine network. Cracks from 3 to 10 mm wide and above are formed as a result of sags or

nonuniform swelling of the ground base, sharp drop of temperature, incorrect working technology. Such cracks are characteristic mainly for asphalt-concrete coverings. A fine network of cracks up to 2 mm wide is formed with the insufficient strength of coverings, poor drainage. Such cracks are observed on asphalt-concrete, crushed stone and gravel coverings, treated with organic binding agent.

Ruts - local destruction of coverings in the form of pits, lenses of various shapes are formed from the effect of the impacts of wheels of the aircraft during passage over the roughness of the coverings with an insufficiently durable surface layer. The ruts are observed on all types of nonrigid coverings. Dents, i.e., the impressions of the aircraft wheels with their prolonged parking, are characteristic for all nonrigid coverings in the hot season with an excess of plastic mixture. The tracks - depressions of coverings in longitudinal direction are formed during poor drainage and overwetting of the soil of the base, with insufficient thickness of covering and low quality of construction work. The tracks are the most characteristic for the simplified and improved types of nonrigid coverings.

Upheavals - these are longitudinal displacements of the surface coverings which occur in sections where large braking forces are developed during aircraft motion; as a result of upheavals there can be breaks of the coverings.

Waviness - inequalities periodically arranged in longitudinal direction in the form of depressions and ridges. It is formed as a result of the displacement of the top layer on the bonding layer or base with excess plasticity of the mixture. Waviness is especially frequent on the coverings treated with organic binding agent by the method of mixing on the spot.

Peeling appears in the form of the stripping of the binding agent from stone materials and is observed with incorrect mixture compositions and with the standing of water on the surface of the covering. Gaps, i.e., damage of coatings to the whole thickness, occurring at places of insufficient thickness of the covering during the periods of intense overwetting of the ground base, are characteristic for the swelling sections of coverings. Wear is a decrease of the thickness of covering as a result of excessive traffic volume with loose mixtures.

Among the basic preventive measures, which decrease the damages of coverings, are: the observance of technology and the high quality of construction, systematic and through care of the coverings, the timely completion of repair work, which is subdivided into routine and major.

Routine repair includes the removal of cracks, sags, tracks, waves, gullys, ruts with the correction of the base, which does not exceed 1% of the entire area of the airfield coverings. Routine repair also provides the sealing of black coverings, repair of the couplings of the coverings with the dirt part of the airfield and the surface flooding of petroleum with the sowing of grit on soil-petroleum coverings. Routine repair is performed regularly during a year on the basis of systematic inspections of the airfield.

The work on the major repair of nonrigid coverings includes: the correction of deformed sections of coverings by means of its dismantling, correction of the base and the placing of a new covering of the same type in the amount of up to 30% of the total area of the airfield coverings; the levelling and reinforcement of the existing asphalt-concrete and black coverings by means of placing a new layer; the elimination of sags on the individual sections of the covering by means of the placement of asphalt concrete or materials treated with black binding agent; the

replacement of the layer of wear on asphalt-concrete coverings or the installation of the surfaces of treatment of black coverings; the repair of damaged crushed stone, gravel and simplified coverings for their adaptation as bases under asphalt-concrete or other types of coverings.

The major repair of asphalt-concrete coverings is performed periodically every 4-8 years; black - 4-8 years; coverings made of untreated crushed stone and gravel - 3-5 years; unpaved improved (soil-crushed stone and soil-gravel) - every 2 years. The major repair of nonrigid coverings, as a rule, includes the reinforcement of coverings. With major repair in most cases the preliminary repair of defects on the old covering is necessary. The technology of the work when reinforcing the coverings is the same as during the reconstruction of the nonrigid type coverings, examined below. The work on the repair of nonrigid coverings should be performed in dry weather, when it is possible to provide good quality of the work.

To provide for the routine repair of coverings on the air-field there should be created annual reserves of repair materials, which include gravel, fractionated crushed stone, bitumen of various brands and the necessary chemical materials.

#### § 80. METHODS OF THE REPAIR OF NONRIGID COVERINGS

Asphalt-concrete coverings. Cracks on the covering depending on their thickness are filled with bitumen or mastic. Cracks up to 5 mm wide are cleaned with compressed air or metal hooks, smeared with liquid bitumen with the aid of a stiff brush, and then filled with hot bitumen SG-130/200, MG-130/200, BND-200/300 or bitumastic heated to 160-170°C.

Cracks wider than 5 mm after cleaning with steel hooks or steel brushes and blasting with compressed air, are smeared with liquid bitumen SG-15/25 and filled with bitumastic. The compositions of mastics are given in Tables 67, 68. Cracks wider than 10 mm are filled with mastic to 2/3 of the depth, and the remaining part - with cold asphalt concrete. The surface of the cracks is rubbed with fine hot sand with the aid of a hot metal drag.

Table 67

Materials entering the mastic composition	Climatic zones					
	II	III and IV	II	II and III	III and IV	
	Number of composition					
	1	2	3	4	5	6
	For the filling of seams 8-25 mm in width			For the filling of seams 6-8 mm in width		
Bitumen BND-90/130, BND-60/90, BND-40/60, %	60	60	60	80	70	60
Mineral powder, %	25	25	20	10	25	35
Asbestos grit, %	10	15	20	-	-	10
Rubber grit, %	5	-	-	10	5	5

Note. Rubber grit should be not more than 2 mm in size, and the waste, obtained during the recovery of rubber - low-plastic particles - 0.1-0.15 mm in size.

The asphalt-concrete coverings are patched in the following manner. The boundaries of the damaged places are marked by chalk with straight lines, parallel and perpendicular to the axis of coverings, encompass 3-5 cm of the undamaged part of the covering. Further we chop out the asphalt concrete to the depth of the rut. The place being repaired is thoroughly cleaned by



Table 68

Materials entering the mastic composition	Mastic		
	Izol 1	Izol 2	Izol 3
Rubber grit, %	14.2	24.0	19.4
Bitumen BND-60/90, %	50.0	33.0	34.0
Bitumen BND-40/60, %	14.3	36.0	19.4
Coumarone resin, %	3.5	7.0	4.9
Asbestos, %	14.5	-	19.4
Rosin, %	3.5	-	-
Polyisobutylene, %	-	-	2.9

wire brushes and smeared with liquid bitumen A-1 or B-1 with the consumption of binding agent  $0.3-0.5 \text{ l/m}^2$ , hot asphalt-concrete mixture is placed with layers not more than 5 cm and is packed in layers by pneumatic rammers, vibration packers or heated metal rammers. With a large area of ruts being filled up they are packed by rollers weighing 5-10 t. After packing the mating place of the repaired sections with the old covering it is smoothed out with a hot metal drag. Small waves and upheavals, which are formed on the asphalt-concrete coverings, are removed by heating the asphalt concrete with heat engines with subsequent levelling by hot metal drags and rammers.

Large waves and upheavals on small areas are removed by cutting down the ridges of waves and upheavals and by the subsequent filling of these places with hot asphalt-concrete mixture over the entire area being repaired. On sections where the waves and upheavals were formed on considerable areas, the layer of asphalt concrete on the entire area is replaced.

With the deformation of coverings, caused by the destruction of bases, the defective sections are cut out and removed, the base is repaired, asphalt-concrete mixture is placed and packed by rollers.

For the reduction of wear of the top layer of asphalt concrete, peeling and pitting the covering is cleaned with wire brushes, primed and the ruts are filled up with crushed rock, treated with binding agent. Further hot bitumen is poured and oiled crushed rock is sprinkled on. The scattered crushed stone is tamped down by rollers. With considerable wear of the surface layer it is restored anew by fine-grained asphalt concrete.

For the repair of asphalt-concrete coverings we use the set of special tools (Fig. 111). The set of tools is placed on a special vehicle.

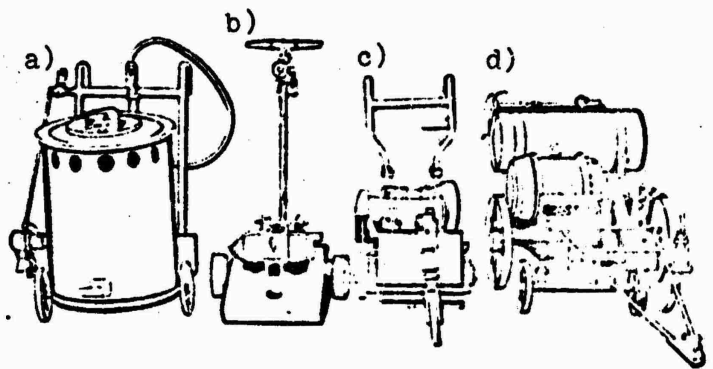


Fig. 111. Tools for the repair of asphalt-concrete coverings: a) seam pourer D-205A; b) electric vibrator D-208A; c) electric brush D-206A; d) electric cutter D-203A.

The repair of black crushed stone coverings and coverings made of gravel and crushed stone mixtures, treated with organic binding materials, includes the removal of ruts, tracks, waves, roughness on separate sections, the restoration of the surface treatment layer.

During the repair of coverings, constructed by the impregnation method, the defects are cut out so that a "box" of rectangular shape with vertical walls would be formed. Its walls are lubricated with bitumen BND-90/130 or BND-60/90 and sealed with fractional

crushed stone by impregnation with bitumen BND-90/130, BND-60/90 and packed.

On the coverings, constructed by the method of mixing on the spot, the defects are picked to the depth of the ruts, tracks, etc., so that the walls would have steep edges, the base and walls are lubricated with bitumen BND-200/300 or BND-130/200 at a rate of  $0.5-0.8 \text{ l/m}^2$  and there is packed a mixture of crushed stone or gravel of the same composition from which the covering was constructed, they are thoroughly mixed and packed. Then over the surface of the sealed place we pour bitumen BND-200/300, BND-120/200, heated to  $110-120^\circ\text{C}$ , and pour on stone grit of fractions 5-10 mm or fine gravel and pack with motorized metal rollers. For the repair work we use movable road oilers with capacity 200 liters with pump, hose and movable boilers. For the scraping of coverings the repair crews have a compressor with a pneumatic tool.

With numerous fine ruts, pitting, peeling and considerable wear of the surface treatment, which cannot be corrected by patching, on the covering we construct a second single or double surface finish depending on the degree of wear of the covering.

With a single surface treatment first we thoroughly clean the covering with mechanical brushes. Then we preliminary impregnate the coverings with bitumen A-1 or B-1 according to the norm of  $1 \text{ l/m}^2$ . Further we pour on bitumen BND-200/300 or BND-130/200, heated to  $140-170^\circ\text{C}$ , with norm  $1.5-2 \text{ l/m}^2$ . Immediately after the spreading of bitumen, while the binding material still has not cooled off, we pour on hot clean and dry stone grit of fractions 5-10 mm according to norm  $0.8-1.1 \text{ m}^3$  per  $100 \text{ m}^2$ , then with three-four passes of the roller weighing 5-8 t we pack one track before complete cooling of the bitumen and stone grit. For the forming of the surface treatment we perform final packing with light pneumatic rubber rollers.

The double surface treatment includes the following processes. After cleaning and preliminary impregnation we pour on the same binding materials as with single surface treatment according to norm  $3-3.5 \text{ t/m}^2$ , pour a key of fractions 10-15 mm according to norm  $1.2 \text{ m}^3$  per  $100 \text{ m}^2$  and pack. Then we perform the second spreading of bitumen  $1.5-2 \text{ t/m}^2$ , pour on stone siftings of fractions 3-5 mm with norm  $0.4 \text{ m}^3$  per  $100 \text{ m}^2$  and finally pack with light pneumatic rubber rollers or trucks. The key and stone siftings are poured on immediately after the spreading of bitumen, while it has not yet cooled off.

The second surface treatment being conducted at the proper time substantially forwarns and delays the development of deformations and wear of coverings and is an important operational measure.

Simplified coverings are repaired when deep holes, ruts, tracks, sags, wear of the sod covering and defects of microrelief are present on them.

The microrelief of coverings is levelled by planing, which includes the loosening of the top layer of the covering, planing and packing. Loosening is performed with the aid of a scarifier to the depth necessary for the removal of damage, but not less than 3-5 cm, shaping is by a motorized road grader alternately with packing by rollers up to the complete levelling of coverings.

Good results on the levelling of the covering can be achieved only with optimum moisture of the mixture. Therefore with insufficient moisture the coatings are watered, and with excess - are dried. Deep holes, ruts, tracks, sags of coverings are removed by patching in the following manner. The sections, undergoing repair, and the places of the entire covering 20-30 cm adjacent to it are cleaned of dust and contamination, loosened and the loosened material is removed. The formed

excavation is given a rectangular contour by hand, so that a "box" with vertical walls would be formed. Then the bottom and walls of the "box" are wet with water and filled in layers with a specially selected mixture, similar in composition to the material of the covering. Every layer is thoroughly packed by tamping with watering. If the area of the defective places of the covering is small, the repair mixture is prepared in advance. During the repair of considerable areas we loosen and remove the material of the old covering, pack the ground base, then place stone material and above it a layer of special mixture. Further with the aid of mixers or disk harrows we mix the materials and plane with motorized road graders. The planed sections are packed with pneumatic rubber rollers. It is advantageous to combine the repair of simplified coverings with their treatment by black binding materials (liquid bitumen or tar).

The repair and restoration of the sod covering on the sections not treated with black binding agent are performed by the sowing of grasses and sod formers.

The simplified coverings made of soils, treated with inorganic binding agents (cement, lime) and chemical materials, are characterized by considerable rigidity, brittleness, wearability; they are capable of dust formation, peeling, cracking. The repair of such coverings involves the sealing of ruts and tracks, restoration of the protective layer.

The repair of dirt-cement and dirt-lime coverings is produced by cement-dirt mixtures. For the repair of coverings made of soils, treated with chemical materials, there are used dirt-cement, dirt-bitumen and gravel-bitumen mixtures. The sealing of tracks, ruts on coverings is performed by patching. First dust and contamination are removed, then the defective places are cut out and the material removed, the formed

excavation is cleaned and slightly moistened with water. Further on the prepared place we place the repair material and thoroughly pack it. The restoration of the protective layer of coverings, treated with chemical materials, is performed with a new layer of fine-grained asphalt concrete 4 cm thick or a layer of fractionated crushed stone 6-8 cm thick impregnated with bitumen. Before packing the new protective layer we treat the surface with liquid bitumen B-1 or B-2.

When the surface of the covering is subjected to wear, intense dust formation and deformation, we construct the surface treatment by the same method as on black coverings.

Depending on the type of simplified coverings for surface treatment we use the following materials. Coverings made of soils treated with cement and lime, preliminarily impregnated with liquid bitumen B-1; for the basic spreading we use viscous bitumen BND-200/300; BND-130/200. The surface treatment of the coverings made of soils treated with water glass, carbomide resins and sulphate - slop concentrate, is accomplished on a dry surface. For preliminary spreading we use bitumen B-1; for the base - bitumen BND-200/300, BND-130/200. The coverings made of soils treated with shale resin are preliminarily treated with liquid bitumen B-5: for the basic spreading we use bitumen BND-200/300, BND-130/200 or shale resin with chemical solidifiers.

The mineral material used during surface treatment is prepared from solid stone rocks in the form of stone siftings. The use of fine gravel (3-5 mm in size) and coarse-grained sand is allowed.

§ 81. QUALITY CONTROL AND ACCEPTANCE  
OF WORK. SAFETY ENGINEERING

During the repair of coverings there is performed thorough quality control of the materials used, the technology of work and the repaired covering. The laboratory workers systematically check the quality of mineral materials, check their physico-mechanical properties; for the binding agents there are checked the viscosity and temperature at the moment of use; the designed mixture compositions are checked also.

During the repair of asphalt-concrete coverings the mixture is inspected by the foreman. It should be movable, not contain clusters of bitumen and mineral materials, not coated by a film of binding agent, and have temperature 130-170°C. During the packing of the asphalt-concrete mixture there is checked the thickness of the layer, the cross fall and evenness by a metal rod and gauge. The discovered discrepancies are immediately removed. During the repair of improved and simplified coverings there are checked the mixture quality, the size of particles, the moisture of materials, the norm and the uniformity of the spreading of binding agent. With insufficient moisture of the mixture we add water, with excess moisture the material is dried.

During the treatment of mixture by binding agent there are checked the uniformity of spreading and the quality of mixing, for which there are conducted laboratory tests of samples taken from the covering. The mixtures should be uniform in composition without excess or deficiency of binding agent. A good mixture does not have clusters of binding agent, and mineral particles are coated with a film of binding agent.

During the repair of coverings made of soils treated with cement, lime and chemical materials there is conducted quality

control of materials, there are checked the designed mixture compositions and the methods of their application during the repair of coverings.

The evaluation of the quality of repair and the acceptance of the executed work are produced on the basis of visual inspection, testing of the strength and evenness of the repaired sections of coverings. The surface of the repaired sections should be uniform, without greasy and dry places, coarse inclusions, and should have identical color.

For testing the strength of the repaired coverings there is performed control aircraft taxiing with gross take-off weight. In this case on asphalt-concrete coverings and coverings constructed by the impregnation method, there should be no tracks; on the repaired sections of the coverings constructed by the mixing method, tracks should not exceed 2 mm. The evenness of the covering is checked by a 3-meter rod. With this the clearance under the rod in transverse and longitudinal direction should not exceed 5 mm. During the repair work with the use of bitumen and chemical materials safety measures and safety engineering should be observed. Workers should be familiarized with the technology of the preparation of mixtures and chemical solutions. During the preparation of bitumen solutions fire-prevention measures should be observed.

When coverings made of soil treated with chemical materials are repaired, special attention is given to safety engineering during the preparation of solutions and repair work. The mixtures of soil with toxic chemical substances, removed from defective sections of the covering, are collected in specially dug pits, located taking into account the place of sampling of water and the runoff of surface water. It is not possible to construct such pits closer than 50 m to a basin. The soil with chemical



substances, collected in pits, should be sprinkled with a layer of natural soil untreated by chemical substances not more than 10 cm thick.

During repair work the technical state of the machines used and the observance of safety regulations and industrial safety measures when working with them should be checked.

## CHAPTER XIX

### THE MAINTENANCE AND REPAIR OF MAT SURFACE COVERING MADE OF METAL PLATES

#### § 82. TYPES OF FAILURES AND DEFORMATIONS

The basic failures and deformations of metal coverings are observed on the take-off sections of the RW, RD and partially on the MS of the aircraft. In these places, the coverings are subjected to the intense effect of the moving, often repeated loads from the wheels and to the effect of the air jets from piston-engine aircraft and the gas flows of the jet engines.

As a result of the repeated passes of the wheels of the aircraft and the effect of the jets and gases of the engines the accumulation of residual deformations of the ground, the blowing-out of the base and the formation of sags occur. The breakdown of the closeness of fit of the metal plates to the base causes the sagging of individual sections of the coverings and intense development of permanent sagging of the plates, which entail inadmissible failures and deformation of the coverings.

With large residual deformations of the coverings deep ruts develop and the breaking of hooks and connecting pieces, the failure of scarf joints and the inadmissible bending-back of the edges of the plates occur. The strength of their fastening in the

perforated plates and MPP-1-53, MP-1-51 plates and of the end strips of the K-1-D plates is destroyed. As a result of such defects, the plates are disconnected and the covering becomes unsuitable for operation. Operating experience also showed that the failure of the metal coverings is observed in places of the adjoining of the RD to the RW with poor quality accomplishment of the weld seams and splices in fastening the coupled sections of the coverings. In a number of cases, if the end and side edges of the covering are unreliably fastened, with repeated passes of the wheels of the aircraft the raising of the plates occurs, which is also inadmissible. Under the influence of atmospheric factors and the aircraft wheels, the painting of the surface is destroyed, which causes corrosion and the failure of the plates.

To assure operating safety of the aircraft on the metal surfaces thorough maintenance and routine repair should be organized. After 3-5 years of operation of the metal coverings their major repair is usually performed, which includes the following work: the repair of the artificial and natural bases of the coverings by pouring additional mineral materials through the perforation or by the dismantling of the plates of up to 50% of the area of the metal covering; the replacement of damaged plates in the amount of up to 25% of the entire area of the metal covering with the repair and straightening of the deformed plates on a flattening machine or by hand; the preservation and representation of reserves of metal plates regardless of their place of storage.

#### § 83. METHODS FOR MAINTENANCE AND REPAIR OF METAL COVERINGS. THE ORGANIZATION OF WORK. ACCIDENT PREVENTION

The maintenance of the metal coverings consists of inspection and care. In the inspection which is conducted daily before and after flights attention is turned to the closeness of fit of the

covering to the base, the presence and the quality of the pins and end strips are checked, the reliability of the weld seams or wire twist joints in the connection of the RD and RW is checked, the dependability of the fastening of the longitudinal and the end runway edges is established, and sections of the coverings on which there are foreign objects and minor damage are disclosed.

Care of the metal covering consists of the cleaning of mud, stones, wire, broken pins, end strips, etc., and the elimination of minor defects for it. Coverings are cleaned by mechanical brushes.

The minor defects - bending of hooks and connection pieces, the elevations of the end plates, the rupture of wire twist joints, the emplacement of new pins or end strips - are eliminated without removing the plates from the covering. More substantial defects are eliminated during routine repair, which includes the restoration of the base, replacement of defective plates, repair of damaged plates and restoration of the painting of the coverings.

The restoration of the minor damage to the bases on the MPP and MPP-1-53 plates that have perforated openings is accomplished by the pouring of additional dirt through openings into the base. For this, the sections with the sagging plates are lifted by small crowbars or by a vehicular crane and the dirt is added through the openings in the plates. If the base of the coverings is damaged over a large area, for the restoration of the base the covering is dismantled. If the dirt base is heavily waterlogged, the liquidized dirt is removed. The hollows formed from the removed liquidized soil and the blowing-out of the base are filled with a sand-gravel mixture and treated with bitumen. Then the plates are laid on the repaired section. To restore the damage to the base, on the coverings of plates MP-1-51, MP-2-51, and K-1-D, which do not have openings, it is necessary to remove

one plate on the subsided section to place channel bars in the opening formed beneath the connection of the plate; further, a vehicular crane should lift the channel bar with the plates adjacent to the opening and additional soil should be poured into the space which has been formed and it should be levelled out and packed. Then the channel bar with the plates is lowered and the laying of the removed plate is accomplished.

The plates which have considerable residual deformations, or the breaking of several adjacent hooks or connecting pieces should be removed from the covering and replaced by new ones. For the replacement of defective plates, it is necessary to remove the pins in the MPP-1-53 and MPP-1-51 plates or the end strips in the K-1-D plates, to shift the plates for the release from adjacent sections, and to remove them from the covering. The laying of the new plates is performed in reverse order. Insignificant damage is corrected manually (the straightening of plates, the restoration of hooks and connecting pieces with the aid of welding).

Heavily deformed plates are straightened on special metal machines by the rolling method; the hooks are repaired simultaneously. The painting of the plates, from which the rust and mud have been cleaned, is accomplished with a special paint or bitumen BND-60/90 dissolved in gasoline. The newly painted plates require drying.

Work on the repair of metal coverings is performed by brigades consisting of two-three sections. The first section (one or two men) removes the pins with the aid of pin extractors or the end strips at the K-1-D plates with small crowbars; the second section (two men) dismantles and emplaces the plates; the third section repairs the base. With insignificant damage to the coverings, the repair work can be accomplished by one section. The repaired sections should be tested by the passes of loaded MAZ-200 or ZIL-150 vehicles at maximum running speed and with abrupt braking.

The vehicles should make several passes along and across the RW. The repaired section of the covering can be accepted for operation, if no significant sagging or defects in the connection of the plates and fastening of the edges have been detected in the tests.

During the repair work it is necessary to observe accident prevention; for this workers should be taught the roles of the assembly and dismantling of metal coverings. Workers are supplied with overalls, gloves, goggles and tools in good working order for the repair work (with pin extractors, small crowbars, sledge hammers, hammers and others). When the work is accomplished in the restoration of the bases with the use of bituminous materials, fire-prevention measures should be observed. In the lifting of the individual sections of the plates for the restoration of the bases the workers are forbidden to be under the crane truck. The fixing of heavily deformed plates on the machines with an electric drive should be performed by workers who have the necessary qualification.

## CHAPTER XX

### THE RECONSTRUCTION OF THE RIGID AND NONRIGID TYPE COVERINGS

#### § 84. PRINCIPLES FOR RAISING THE BEARING CAPACITY AND METHODS FOR EVALUATING THE CONDITION AND STRENGTH

During the reconstruction of airports the necessity appears for strengthening the existing coverings of RW, RD and MS. As a rule, rigid coverings, and sometimes nonrigid, mainly asphalt-concrete and rough made of crushed stone and gravel mixtures will be subject to strengthening. Coverings are strengthened for the purpose of increase of the bearing capacity and restoration of their efficiency, and also to provide for the operation of new heavier aircraft. The restoration of the efficiency of coverings is necessary when they have a large quantity of defects (ruts, severe wear of top layer, etc.) and they do not facilitate the normal and safe operation of aircraft.

In both cases on the surface of the covering is placed a strengthening layer. During the reconstruction of coverings and the installation of strengthening layers considerable attention should be given to evaluation of the artificial and natural bases of the existing covering, and also to the analysis of the hydrogeological conditions of the object. For revealing the defective sections of bases and evaluating the total strength

of the coverings it is recommended to perform control rolling by mobile testing devices, simulating the design load from the support point of the aircraft.

If the natural and artificial bases of existing coverings have no defects, a strengthening layer is placed without taking any additional measures. If as a result of unsatisfactory physico-mechanical properties of the ground, swelling, and poor draining the base is destroyed, it is necessary to partially replace the swelling soil with sand-gravel material, after which restore the covering, ensuring the designed criteria of the repaired section of the surface. If the base is destroyed due to the malfunctioning of drainage system, then the latter is restored.

When planning the work on the strengthening of existing coverings it is necessary to have the following initial data:

the class of the airfield, for which the covering should be designed, including data on the takeoff weight and the diagram of support points of aircraft, pressure in the pneumatic tires, speeds, distances of the aircraft takeoff and landing run;

the condition of the existing covering, the takeoff weight and the diagram of the support points of the aircraft taking into account the loads to which it was designed, and also data on the inspection of the condition of the existing covering, on the basis of which the plan for strengthening is compiled.

The characteristic plan for strengthening the rigid covering is shown on Fig. 112. In accordance with this plan the rigid coverings being strengthened depending on their condition are divided into three categories.



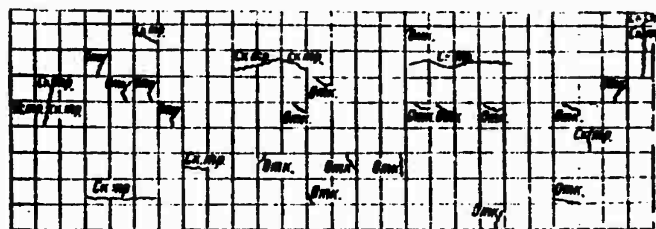


Fig. 112. The plan for strengthening the covering (OHH. - splitting off; CH.mp. - through cracks; Yc.mp. - shrinkage crack).

The first includes sections which do not have visible surface failures (splittings of the edge of plates, mutual raises of plates), also the sections in which up to 20% of the plates have an insignificant number of through cracks. Among the second are the sections which have a large quantity of surface failures (more than 20% of the plates with through cracks, of which up to 10% of the plates have through cracks). The third includes sections with large surface failures, where the quantity of plates with cracks exceeds the number established for the second category.

Besides the category of the covering, it is necessary to have the characteristic of natural and artificial base and data on the hydrogeological conditions, and also the strength characteristics of the concrete of the existing covering, i.e., the ultimate tensile strength of concrete with bending  $\sigma_{p.n.}$  and the elastic modulus of concrete  $E_0$ . These data are established on the basis of research on the design, and also by tests. Considerable attention should be given to determining the quality of the old concrete covering being repaired, since depending on the actual strength of concrete we determine the thickness of the strengthening layer. After prolonged operation the actual strength of coverings is always less than the calculated.

The strength of the existing concrete covering should be determined by testing the concrete samples taken directly from the covering. Samples should be in the form of standard beams and

blanks, taken from the covering, whose size should be not more than  $40 \times 40$  cm. They are compression tested by the stamp method, by which compressive forces are transferred not to the entire piece of concrete, but only to a small area which is located under a two-sided stamp (Fig. 113). Professor P. F. Shubenkin's experiments showed that the test results of blanks for compression by a two-sided stamp are similar to control tests when testing standard cubes:

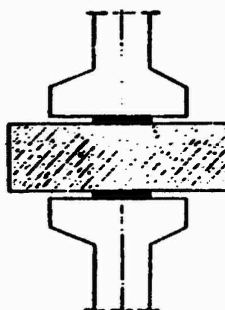


Fig. 113. Diagram of blank test.

Check tests, $\text{kgf/cm}^2$ .....	339	241	184	139
Test by two-sided stamp, $\text{kgf/cm}^2$ .....	338	219	169	131

He noted that during preparation for the test it is necessary to thoroughly align the surface of blanks and tightly install the stamps, using slurry. It is possible to use square stamps with dimension of the side 10-15 cm or round with diameter 10 to 12 cm. On the basis of test data of the blanks we establish the computed values of the ultimate tensile strength of concrete with bending and the elastic modulus of concrete. For example:

Compression strength, $\text{kgf/cm}^2$	300	350	400
Ultimate tensile strength with bending, $\sigma_{pu}$ , $\text{kgf/cm}^2$ .	40	45	50
Standard elastic modulus with bending $E_0$ , $\text{kgf/cm}^2$ .....	300,000	358,000	410,000

Having obtained the enumerated initial data, it is possible to change to the planning of strengthening layers of the rigid coverings being reconstructed.

During the strengthening of nonrigid coverings there is also performed an inspection and the plan is composed. On the plan are plotted ruts, which cause danger for aircraft motion, areas with considerable wear of the top layer of covering, cracks, waves and gaps. Along the longitudinal axis of RW, RD and MS there are established the actual thicknesses and the moduli of deformation of the separate layers of the existing covering. The moduli of deformation of the separate layers are established on the basis of the tests of samples taken from the covering, by a standard procedure under laboratory conditions. The strengthening layers of nonrigid coverings are designed on the basis of the composed plan of defects, actual thicknesses and moduli of deformation of the separate layers of the existing covering.

#### § 85. METHODS OF RECONSTRUCTION OF RIGID TYPE COVERINGS

For an increase in the bearing capacity of the existing covering a strengthening layer is constructed from materials able to resist tension during bending and to absorb part of the bending moment of the design load. For the placement of upper slabs over the existing covering with temperature deformations the strengthening layer in the majority of cases is placed on a separating interlayer. Sometimes the strengthening layer is reliably joined to the existing concrete covering, which during evaluation of the bearing capacity allows considering such a two-layered covering as monolithic. For the strengthening layer of existing coverings of the I and II category it is possible to use concrete, reinforced concrete, prestressed concrete, and also asphalt concrete, while for coverings of the III category - asphalt concrete. Asphalt concrete is also widely used in the reconstruction of airports, for the restoration of the efficiency of coverings.

Increase of the bearing capacity of coverings by means of the creation of a second layer of concrete can be accomplished by using the first method, when a strengthening layer is placed on the separating interlayer and by using the second method with the provision of solidity of both layers. In the practice of airfield construction the first method received the greatest use. It is simpler with respect to the conditions of production of work, since it does not require the mandatory matching of joints in the old covering and in the strengthening layer.

During the joining of concrete this requirement is mandatory to avoid the cracking of the strengthening layer over the joints of the covering being strengthened. The strengthening layer in both methods is separated by standard rectangular slabs. The longitudinal and transverse joints of rectangular concrete slabs of the strengthening layer are constructed according to the type of expansion and compression joints just as in ordinary concrete coverings, the edge sections of slabs are strengthened by butt joints or reinforced. By placing concrete on the separating interlayer, it is advantageous to arrange the slabs of the top layer, i.e., strengthening layer, so that their corners would be placed on the center section of the slabs of the covering being strengthened (Fig. 114). Such placement is always possible and it improves the operating conditions of the corner sections of the slabs of the strengthening layer. The material of the separating layer should be selected on the strength of the following basic requirements: the elimination of adhesion between the old and newly placed concrete; the provision of evenness of the surface, on which the strengthening concrete is placed; the provision of watertightness of the coverings in order to eliminate surface water getting into the base.

The material of the separating interlayer should be resistant to washing out by water, and also be sufficiently cheap and

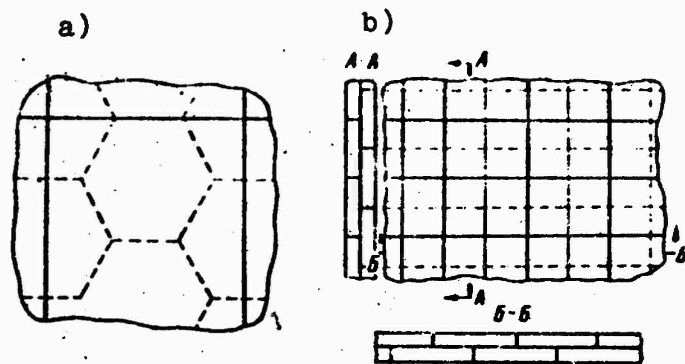


Fig. 114. Diagram of the placement of rectangular slabs of the top layer relative to the slabs of the covering being strengthened: a) bottom layer made of hexagonal slabs (dotted line); b) bottom layer made of rectangular slabs (dotted line).

convenient during the production of work. Material for the interlayer, satisfying the indicated requirements the most, is a sand-bitumen mat. It is inadmissible to use the interlayer in the form of a bituminous coating or a sand layer, placed directly on the surface of the covering being strengthened or on bituminous covering. The separating interlayer should also serve for levelling of the surface of the covering being strengthened. This is admissible when the surface defects of the old covering are insignificant: drops in high position of the slabs are not more than 0.5-1.0 cm; the depth of surface failure is not more than 0.5-1.0 cm, etc.

With considerable defects of the old covering the levelling is accomplished by cement mortar. The cement mortar is used, as a rule, for levelling the separate places of the covering being strengthened, when there are places with clearly expressed sag of slabs, surface failures to a depth over 1-2 cm and others. The places of splittings of concrete on the faces of slabs are also restored by cement mortar or by fine-grained concrete. In this case the surfaces should be given designed gradients and careful finishing be provided for. On the levelling layer is applied a sand-bitumen mat.

The joining of the old and newly placed concrete is used less often, although a number of advantages is inherent to it. The main advantage of this method is the fact that when joining concrete the construction of a separating layer and the preliminary levelling of the surface of the old covering are not necessary. With the joining of the old and newly placed concrete it is recommended to construct notches on the surface of the old concrete.

The surface of the old covering should be cleaned, washed and moistened immediately before the placement of the second layer of concrete. The experimental testing of the joined constructions by vertically applied loads showed that the character of damage completely corresponds to the damage of monolith, and the magnitudes of breaking loads are close to the corresponding loads for the equivalent monolithic covering. The difference in loads does not exceed, as a rule, 10%, i.e., the load at which failure of the joined construction occurred, comprised 90% from the breaking load for cast-in-situ concrete. A considerable shortcoming of this method is the necessity for strict matching of slabs in the old and newly placed coverings. This requirement in a number of cases eliminates the use of slabs of optimum shape and dimensions, and also complicates their butting.

Increase of the bearing capacity of coverings with build-up of the layer of reinforced concrete is today one of the most effective means of the strengthening of coverings. The placement of a layer of reinforced concrete on the existing covering is performed on a separating interlayer. With the laying-out of slabs of the top layer it is necessary that the corners of reinforced concrete slabs be placed on the center section of the slabs of the covering being strengthened. The strengthening layer of reinforced concrete is made of rectangular slabs  $7 \times 20$  (25) m in size. The thickness of slabs is taken according to calculation.

The approximate construction of reinforced concrete slabs  $20 \times 7 \times 0.18$  m in size is given in Fig. 115.

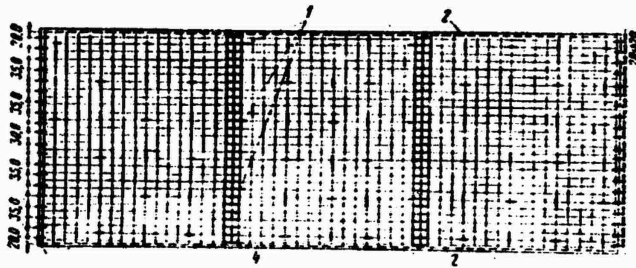


Fig. 115. The construction of reinforced concrete slab of the strengthening layer: 1 - installation eyes; 2 - tongue and groove joint; 3 - pin joint; 4 - place of installation of nets.

Longitudinal seams in the covering made of slabs more than 18 cm thick are constructed tongue and groove according to the type of expansion and compression joints. The compression and expansion joints have the same construction as for concrete slabs. With the thickness of the reinforced concrete layer less than 18 cm it is difficult to make tongue and groove joints of good quality. Therefore in slabs with comparatively small thickness of the top layer instead of tongue-and-groove joints it is possible to use through joints with calculated reinforcement of their edges. Transverse joints should be constructed as pinned with the same construction as for concrete coverings. For the reinforcement of slabs we use reinforcing nets, which are welded with the aid of jigs with the mandatory welding of all junctions along the perimeter of the net. The remaining junctions are welded every other one in checkerboard fashion. The reinforcing nets are welded to installation eyes in the amount of 78 pcs. per slab with dimensions  $20 \times 7$  m. After placement the extreme rods of the upper nets are welded to the rods of the lower.

During the installation of the built-up layer of reinforced concrete the thickness of the slabs can be decreased as compared with the thickness of slabs of the top layer of concrete by 1-2 cm.

Increase of the bearing capacity of coverings with cast-in-situ prestressed concrete of slabs of large sizes in the plan ensures reliable work even on highly damaged old concrete coverings. For an increase in the bearing capacity in this case there can be used the same constructions of prestressed cast-in-situ coverings as for the building of new sections.

Between the old concrete and the strengthening layer there is constructed a separating layer; if necessary the surface of the strengthened covering is levelled by cement mortar or by fine-grained concrete. The prestressed strengthening layers with the tightening of reinforcement to the hardened concrete must be placed so that the technological breaks between the sections of slabs would be placed over the sound sections of the old covering, and the longitudinal construction joints do not match the longitudinal seams of the old covering. If the covering is damaged so much that it is impossible to place technological breaks over undamaged sections, in the zones of these technological breaks it is necessary to remove the old damaged slabs and install the same underseam slabs as during the construction of new sections of coverings with the tightening of reinforcement and concrete.

The use of longline prestressed concrete coverings for the strengthening layer has a number of essential advantages as compared with the type coverings examined above. Longline prestressed concrete coverings do not have frequently repeating technological breaks of considerable width. Therefore there is no need in the removal of old damaged coverings in the zones of the transverse expansion joints. When the old covering is very damaged, in the transverse expansion joints there are set up additional pin connections, which facilitate the combined work of the adjacent end sections of longline prestressed concrete slabs after cutting the wire or rod reinforcement in the joints. The construction of anchor plates for longline prestressed concrete strengthening layers also depends upon the condition of the



coverings being strengthened. If it is in satisfactory condition then the anchor plates, being placed along the length of the covering every 500-1000 m, can be placed directly on the old covering with the application of the necessary measures for reliable cohesion between them. In the case when the old covering is highly damaged and cannot be a reliable support for the anchor plate, in the zones of future anchor plates the old covering is removed, and the anchor plates are made the same as when building new sections of longline prestressed concrete coverings.

The strengthening layer can be single-frame compressed and two-frame compressed. Single-frame compression is used when the covering being strengthened can be attributed to the I and II category. For the strengthening of coverings of the III category the use of two-frame compression is compulsory.

Increase of the bearing capacity of coverings by prestressed slabs is accomplished from reinforced-concrete slabs of plant manufacture PAG-IX and PAG-XIV. In this case the covering being strengthened is levelled with dry sand-cement mixture, which is prepared from medium-grained sand with consumption of about 250 kg of cement for 1 m<sup>3</sup> of mixture. The levelling layer is placed immediately before the installation of slabs so that the setting of cement in it would not begin until the completion of work. When the old covering is highly damaged and the local roughness reaches 8 cm and more, it is necessary to preliminarily level the separate depressions with concrete or sand-cement mortar so that the levelling layer would have thickness not more than 6-8 cm. It is necessary to arrange the slabs of the strengthening layer with the long side along the basic direction of aircraft motion, so that the longitudinal and transverse joints of the strengthening layer would not coincide with the joints in the old covering.

Increase of the bearing capacity of coverings with asphalt concrete is accomplished in one and two layers (Fig. 116). The

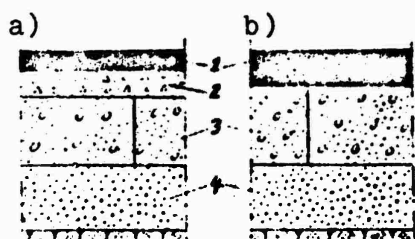


Fig. 116. The construction of strengthening layers of concrete coverings with asphalt. a) two-layer; b) single-layer 1 - top layer of asphalt concrete covering; 4 - artificial base.

construction of the strengthening layers, the composition of asphalt concrete and the technology of their placement are the same as during the installation of the ordinary nonrigid asphalt-concrete coverings examined above.

Before the placement of asphalt-concrete mixture from the surface of the existing concrete covering it is necessary to remove dirt, crushed stone and other foreign objects. If the surface of the concrete covering has a large quantity of holes, cracks and other defects, it is necessary to preliminarily smooth out these sections with asphalt-concrete mixture. In all cases for the best cleaning of the covering being repaired it is desirable to blast its surface with compressed air. To the cleaned surface we apply a thin layer of bitumen, diluted with kerosene, at a rate of  $0.6-0.8 \text{ kg/m}^2$  and after its drying it is possible to place the asphalt-concrete mixture. Bitumen is poured not in a solid layer, but in the form of a grid. The asphalt-concrete mixture is placed in hot state in layers with packing by rollers. The work must be performed in dry and warm weather, in order to ensure its high quality.

During the operation of concrete coverings, reinforced by asphalt-concrete mixtures, there can appear cracks, sags, high places, pits, etc., which decrease the bearing capacity of coverings, and therefore thorough operational care of the asphalt concrete is necessary. One should not allow the development of

damages on the surface, for which immediately upon their detection it is necessary to fill them with hot asphalt-concrete mixture, rub over them with hot drags.

For increase of the stability of the coverings being repaired it is advantageous to reinforce the asphalt-concrete strengthening layers. When the old covering has a considerable quantity of cracks, splits, etc., it is recommended to apply continuous reinforcement of asphalt concrete with welded nets made of wire 2-3 mm in diameter with mesh  $10 \times 10$  cm or  $7.5 \times 15$  cm. The layer of asphalt concrete over the reinforcing net should not be less than 45 mm.

With the presence of single cracks on the concrete covering being repaired it is recommended to use strip reinforcement. For the overlap of transverse cracks or joints we use strip nets 2.5 m wide, while for the overlap of longitudinal cracks or joints the width of nets is 1.5 m.

With the restoration of the efficiency of the old concrete coverings asphalt concrete is placed in one layer 4-6 cm thick.

The increasing volumes of Aeroflot passenger transport advance a number of new questions during the reconstruction of airports. Among these primarily is the development of methods for strengthening the cement-concrete coverings with asphalt concrete without interruption of the airport operation. The works of Prof. A. A. Kalert, Doctor of Technical Sciences N. G. Porfilov, A. P. Zodotov, V. V. Leonovich, G. A. Komatovskiy and G. A. Oparin have been dedicated to this important question.

The strengthening of the cement-concrete covering by asphalt concrete without interruption of operation was successfully accomplished at one of the Aeroflot airports. The success of this work was achieved as a result of the use of asphalt concrete, which

allows the operation of the covering already several hours after packing (rolling). The strengthening layers were two-layer with total thickness 11-12 cm (bottom layer 6 cm and upper 5-6 cm). For the bottom layer there is applied coarse-grained asphalt concrete, for the upper - fine-grained of increased quality.

During the placement of asphalt concrete the following measures were taken, providing safe takeoff and landing operations: regulated working time, connected with the variation of the flight schedule of aircraft; the selection of special routes of movement of the trucks, taking into account the paths of aircraft taxiing; the use of powerful illuminators (floodlights) during night work; the weather minimum for the receiving of aircraft has been determined.

The concrete coverings of a runway reinforced in this way after 2-3 years of operation are in good condition, which indicates the real possibility of strengthening airport coverings by asphalt concrete in short periods without interruption of airport operation.

For the reliable operation of coverings during their reconstruction it is necessary to pay special attention to the establishing of the thickness of the strengthening layer. The thickness of the strengthening layer is established proceeding from the condition of the existing covering, hydrogeological conditions of the airport and the accepted construction.

The thickness of concrete strengthening layers of rigid coverings is determined by formula

$$h_{\text{верх}} = k_1 h - k_2 \frac{E_1}{E_2} h_{\text{нижн}} \quad (84)$$

[Translator's Note: верх = top; нижн = bottom.]

where  $h$  - the thickness of the cast-in-situ concrete covering of the top layer, calculated for the new load, cm;  $E_1$  and

$E_2$  - the elastic modulus of materials of the covering and strengthening layer respectively;  $K_1$  and  $K_2$  - experimental coefficients determined according to Table 69. Formula (84) is applicable when  $E_1/E_2 = 1-0.7$ .

Table 69.

Category of the covering to be strengthened	Joining		Build-up on the separating interlayer	
	$k_1$	$k_2$	$k_1$	$k_2$
I	1.05	1.00	1.1-1.2	1.0
II	1.05	0.85-0.95	1.1-1.2	0.85-0.95
III	-	-	1.2-1.3	0.8-0.9

During the strengthening of the existing concrete covering by asphalt concrete the thickness of the strengthening layer can be determined by N. N. Ivanov's formula

$$h = (H - h_1) \sqrt[3]{\frac{E_1}{E_2}}. \quad (85)$$

where  $H$  - the necessary thickness of single-layer concrete covering for the given calculated load, cm;  $h_1$  - the thickness of the existing concrete covering (bottom layer), cm;  $h$  - the necessary thickness of asphalt-concrete strengthening layer (top layer), cm;  $E_1$  and  $E_2$  - the elastic modulus of concrete and asphalt concrete respectively,  $\text{kg/cm}^2$ .

During the restoration of the efficiency of concrete coverings with asphalt concrete the thickness of the strengthening layer is designated constructively, and the existing concrete covering is checked for strength with the calculation for the new load taking into account the increased diameter of the load area, determined by using formula

$$d_1 = d - 2h_2, \quad (86)$$

$d_1$  - the equivalent diameter of the area of transmission of load on the existing covering, cm;  $d$  - the equivalent diameter of the area of transmission of load to the strengthening layer, cm;  
 $h_2$  - the thickness of the strengthening layer, cm.

#### § 86. METHODS OF RECONSTRUCTION OF NONRIGID TYPE COVERINGS

Asphalt-concrete coverings are strengthened by a layer of asphalt concrete, placed directly on the covering or on intermediate crushed stone layer. The existing black crushed stone coverings, being constructed by the impregnation method, and also black coverings of gravel and crushed stone mixtures, being constructed by the mixing method, are strengthened by: the placement of a layer of oiled crushed rock directly on the covering or on an intermediate crushed rock layer; asphalt concrete being placed directly on the covering, on an intermediate crushed rock or on a layer of black covering.

Simplified black earth and gravel (earth and crushed rock) coverings are strengthened by placing a layer of earth and gravel (earth and crushed rock), fastened by black binding material, directly to the covering; by a layer of oiled crushed rock placed directly on the covering or on an intermediate crushed rock layer; by asphalt concrete.

It is recommended to strengthen simplified dirt coverings, fastened by binding agent, with a layer of black earth gravel (earth crushed rock). All types of nonrigid airfield coverings can also be strengthened by rigid coverings. Nonrigid coverings in this case are considered as the bases of rigid coverings. For strengthening it is possible to use concrete, reinforced concrete

and prestressed ferroconcrete slabs of plant manufacture PAG-IX and PAG-XIV. The type of strengthening of nonrigid coverings is selected on the basis of new assigned calculated loads, the presence of local structural materials, and also on the basis of the technical and economical comparison of different variants.

The construction of strengthening layers, the materials used and the building technology do not at all differ from the ordinary nonrigid coverings examined above. A feature during the reconstruction of nonrigid type coverings is only the surface preparation of the old covering. The surface of the existing asphalt-concrete coverings is levelled before the placement of the strengthening layer. In this case large waves and upheavals are removed by chopping off their crests; small waves and rolls are completely cut off. For the best cohesion of the asphalt-concrete layer with the old asphalt-concrete covering the surface of the latter is smeared with diluted bitumen at the rate of  $0.1-0.2 \text{ l/m}^2$ . After smearing we place the asphalt-concrete mixture, level and pack with rollers, first with light weighing 5 t, and then with heavy weighing 10 t. During the strengthening of crushed stone coverings it is also initially necessary to level the surface of the old covering. For this sags, deep ruts, and tracks are repaired. Then continuous scarifying of the coating to a depth not more than 5 cm is performed. The scarified crushed stone is removed from the covering and on the surface of the old crushed rock a layer of new crushed rock is scattered. After this planing and packing are accomplished. The spreading of binding agent and rolling are accomplished as during the installation of nonrigid coverings. The levelling and the repair of the surface of the old covering must be performed preliminarily during the strengthening of simplified earth coverings.

The thickness of the strengthening layer of existing nonrigid type coverings is determined taking into account the new load from

the aircraft and the mechanical characteristics of the materials of strengthening layers.

The calculation of the strengthening layer of the covering is performed in this sequence:

1) thickness  $H$  is determined for the new design load with the modulus of deformation of the material  $E_1$ , comprising the main part of the existing construction;

2) the given thickness of the existing construction  $H'_c$  is calculated. Thickness  $H'_c$  is found by reduction of the existing construction to the modulus of deformation  $E_1$ , which corresponds to the material of the main part of the construction:

a) for two-layered covering

$$H'_c = h_1 + \frac{h_2 \sqrt[2.5]{E_2}}{K_2} \sqrt[2.5]{\frac{E_2}{E_1}}; \quad (87)$$

b) for three-layered covering

$$H'_c = h_1 + \frac{h_2 \sqrt[2.5]{E_2}}{K_2} \sqrt[2.5]{\frac{E_2}{E_1}} + \frac{h_3 \sqrt[2.5]{E_3}}{K_3} \sqrt[2.5]{\frac{E_3}{E_1}}. \quad (88)$$

where  $h_1, h_2, h_3, E_1, E_2, E_3$  - the thicknesses and moduli of deformation respectively of the separate layers of the existing covering;  $K_2, K_3$  - coefficients of influence of the modulus of deformation of the underlying system, magnitudes and schemes of the application of load, which correspond to parameters  $E_2$  and  $E_1$  (determined by SN 120-60);

3) there is determined the thickness of the strengthening layer, reduced to the modulus of deformation of the material, comprising the main part of the existing construction ( $E_1$ )



$$H'_y = H' - H'_c; \quad (89)$$

4) the thickness of separate strengthening layers is calculated taking into account the actual moduli of deformation of the materials used. During the strengthening of the coatings by one layer the thickness of strengthening  $h_{y1}$  is determined by formula

$$h_{y1} = \frac{H'_y K_{y1}}{\frac{E_{y1}}{E}} \quad (90)$$

Coefficient  $K_{y1}$  characterizes the relationship of the actual modulus and the modulus of material comprising the major portion of the covering, safety factor and type of aircraft support (varies within 0.40-0.90). The thickness of separate layers with two-layered strengthening of coverings is calculated similarly;

5) the overall thickness of the reinforced covering is determined

$$H_y = H_c + h_{y1}, \quad (91)$$

where  $H_c$  - the overall thickness of the existing covering, cm.

During the strengthening of coverings for the purpose of restoration of their efficiency the thickness of the newly placed layer is established constructively.

## CHAPTER XXI

### MAINTENANCE AND REPAIR OF THE SURFACE- DRAINAGE NETWORK OF AIRFIELDS

#### § 87. METHODS OF MAINTENANCE OF THE SURFACE- DRAINAGE NETWORK IN THE DIFFERENT SEASONS OF THE YEAR

The service life of airfield coverings and the reliability of operation of dirt flightways depends to a considerable degree on the state of preservation of the surface-drainage network. For maintaining the surface-drainage networks in constant operational readiness it is necessary to give special attention to their maintenance, which consists of systematic inspection and care. Serious defects of the surface-drainage network, revealed during inspection, are removed by timely repair.

The inspection and care of drainage and sewer networks are conducted by the airport service. The routine inspection of networks is conducted systematically during the entire year. The special inspection of surface-drainage networks is conducted in the spring after the snow melts and in the autumn after the fall of heavy rains. All manholes and storm wells, drain lines, open elements and their constructions, and also the surface of the soil around constructions and over buried pipelines will be subject to inspection. For the inspection of pipelines we use mirrors and lamps. For the detection of blockages, silting in adjacent wells

of the pipeline we install a mirror and lamp. The light of the lamp is directed along the pipe being inspected to the mirror, by the image on which it is possible to judge the condition of the pipe. The inspection of large diameter pipes (more than 0.8 m) is conducted by a worker who crawls inside them with a lamp. Care of the surface-drainage systems involves the cleaning of storm wells and manholes, pipelines and open constructions and systems from dirt, debris and alluvial soil.

During the spring snow-melting period open gutters, ditches and pipe ends are cleaned of ice and snow. The unburied elements of the network and construction are cleaned immediately after their inspection. The ditches are cleaned of silt. In order to eliminate the backwater effect in surface-drainage systems, the places of coupling of ditches with water intakes (ravines, streams, etc.) are thoroughly cleaned. In sewer and thalweg wells lower than gratings we pack straw mats, which decrease the contamination of wells by surface water. The cleaning of buried manholes is produced in the spring. For cleaning the wells it is necessary to preliminarily remove the sod in slabs and remove the soil over the cover, then remove the cover and clean the well. After cleaning it is necessary to close the cover, cover it with soil and replace the earlier removed slabs of sod. During replacement the soil must be packed in layers and thoroughly tamped. The pipelines are cleaned in spring and in summer and this includes the pushing of brushes (Fig. 117), scoops and scrapers through the pipe from well to well, which loosen the accumulated contamination. Work on cleaning the network consists of the following.

Into the upper well preliminarily through the water we pass a float with a cord. When the float reaches the bottom well, to the cord in the upper well is tied a 5-millimeter rope and it is extended to the lower well. Both ends of the rope are connected to winches installed on the upper and lower wells. To the rope

is fastened a brush or scoop, which with the aid of the winch is pulled between the wells, cleaning the pipes. Sand, silt and

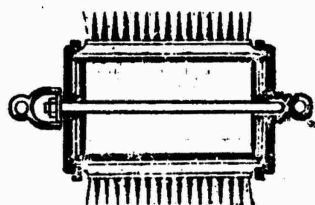


Fig. 117. Brush for the cleaning of pipes.

other deposits, being transferred to wells, are drawn upward. It is advantageous to combine the mechanical cleaning of pipelines with flushing by water under a head from a fire nozzle or from street-sprinkling machines. The scheme of pipe cleaning is shown on Fig. 118.

The pipes can also be cleared with the aid of pipe rods with a brush on the end. Work on cleaning the network is performed just as with the aid of a rope.

The rods with brush are pushed along the pipes between adjacent wells. The separate links of rods are connected together by threaded sleeves. The length of the rod link should not exceed the internal size of the well. In autumn the surface-drainage network is inspected once more

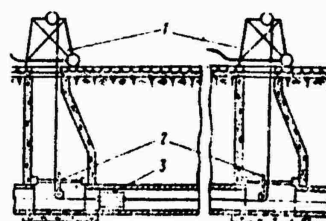


Fig. 118. The scheme of pipe cleaning: 1 - winches; 2 - spacer; 3 - brush.

and if necessary is cleaned. In order to avoid snow drifts, under the grating covers of sewer and thalweg wells we place wooden covers or iron plates. These covers are opened in the spring during the snow-melting period. The covers of sewer and thalweg wells are opened also in winter during thaws and rains for the disposal of water from coverings and the air field. Right after the termination of rains and thaws these covers are reinstalled. For the state of preservation of the surface-drainage network, besides routine care, it is necessary to perform systematic repair.

## § 88. MAIN TROUBLES, REASONS FOR THEIR APPEARANCE

The troubles of the surface-drainage network are damages of open gutters, water inlets, thalweg wells, manholes, cracks in drain pipes, gullies and sags along the courses of drain lines and at drain constructions.

The most characteristic damages of open gutters, located on the edges of the coverings, are cracks in the gutter slabs, sags and gaps of coverings on the entire thickness to the base, breakage of seams. Cracks are formed with a sharp drop of temperature and with nonuniform swelling. Sags and gaps are formed during the period of overwetting of the ground base, during the washing out of draining bases along the length of the gutter. The destruction of seams between slabs occurs under the influence of atmospheric factors, and also because of the insufficiently high quality of work during the sealing of joints. The damage of the open dirt gutters on the shoulders of coverings is formed from the erosion of soil by surface water. With low quality of work and insufficient tamping there are formed subsidences along the routes of buried drainage collecting lines, drains, and sewers.

Drain lines with filtering filling in the course of time are obstructed and filled with mud. The main defects of sewer wells, thalweg wells and manholes are cracks on the walls and bottom, the breakage of grates and covers, the breakage of pipe couplings with the wells, the damage of slabs around the sewer wells.

The breakages of the structures of drain constructions occur mainly because of the low quality of work. The damages of the slabs of sewer wells are connected with the erosion of bases. In drain lines there are observed cracks in pipes, sags of pipe sections, the breakage of butt joints. These damages are connected

with the washing away of the base of pipes, nonuniform settling of pipelines, with nonconformity of the construction of drain pipes to the types of aircraft.

The troubles of open drain systems, located outside the limits of the flying field (ditches, pipe ends), occur as a result of the erosion and sliding of soils. Slides, floating soil and silt fall into ditches and into the points of exit or inlet of water into pipes and obstruct them. Therefore it is necessary to systematically clean these sections of the drain system. Especially careful cleaning should be performed in the spring after the passage of spring water and in autumn - before the onset of frosts.

The noted troubles of surface-drainage networks of airfields are removed by routine and heavy repair. Routine repair is performed during the year systematically and includes the repair of sewer, manhole and thalweg wells, the removal of individual air holes in the walls of wells, drainage networks, the sealing of joints between ferroconcrete elements of wells, the restoration of the tight coupling of pipes with the walls of the wells and overflow chambers; the repair of closed gutters - the sealing of cracks, airholes, the replacement of faulty perforated blocks; the replacement of unit pipes on separate sections of sewer and drainage elements (not exceeding 5% of the overall extent) and repair of separate joints; the elimination of erosion and rain rills along the routes of hidden elements of the drain network up to 10% of their extent; the elimination of erosions in mouth constructions, dirt gutters, open ditches and around manholes and thalweg wells, the restoration and reinforcement of mounds; the sealing of cracks in concrete pipe ends of mouth constructions and overflow pipes; the correction of supports of slopes and the bottom of open ditches (up to 10% of the overall area of supports); anti-corrosive painting of the grates of water inlet and thalweg

wells; the manufacture and replacement of defective units of covers of manholes.

The major repair of surface-drainage networks of airfields is performed periodically: sewer and drainage installations every 3-5 years; protective and supporting constructions every 4-6 years; pipe ends of mouth constructions and overflow pipes every 10-15 years.

During heavy repair the following work is completed: the repair and restoration of sewers, manholes and thalweg wells; replacement of unfit pipes of sewers, overflows and drains in the amount of up to 25% of their total extent; the repair and restoration of drain constructions (closed gutters, open dirt gutters, water drain-off and high ditches and others); the elimination of erosions and rain rills along the routes of hidden and open elements of the network not more than 10% of their extent, the accomplishment of reinforcement work, the restoration and reinforcement of mounds; the repair and restoration of the pipe ends of mouth constructions and overflow pipes; the replacement and washing of filtering fillers in the drainage elements of the network; the repair of bases of pipes and wells on swelling soils with restoration of sewers and wells; rearrangement of elements of the storm sewer system during repair with the replacement of constructions by stronger, more durable and progressive.

§ 89. METHODS OF REPAIR OF SURFACE-  
DRAINAGE NETWORKS. QUALITY CONTROL  
AND INSPECTION OF WORK. ACCIDENT  
PREVENTION

All troubles of the surface-drainage network, revealed during inspection, should be removed at the proper time. For the elimination of defects in open gutters located on the edges of coverings, connected with the washing out of bases, it is necessary

to break up the covering of the gutter, remove the concrete and crushed stone. Then at the places of damage of bases we replace or put on more draining material of the same quality as the material of base. When pouring on it is necessary to thoroughly tamp the draining material.

After the restoration of base we construct the new covering of the gutter from cast-in-situ concrete. Cracks in the concrete gutter slabs and the joints between them are repaired by the method accepted for repair of rigid coatings and expounded above. On the sections being repaired it is necessary to observe the designed gradients of coverings and provide good conditions for the runoff of surface water - transverse and longitudinal seams of concrete slabs are sealed flush with the coverings.

Rain rills and sags on open dirt gutters are filled with local soil with thorough tamping. For restoration of the destroyed sod cover on the sections being repaired we place new layers of sod or sow grass. The surface of the sections being repaired must be thoroughly levelled with the observance of designed gradients.

The sags under the drain pipes placed in the soil are removed by pouring on soil and by tamping. With failure of the filtering filling, entering the surface of the soil near dryers, as a result of rain rills and erosion it is necessary to add new filtering material. In the course of time there occurs silting of the filtering filling in dryers and drains, as a result of which the normal operation of the surface-drainage network is disturbed. In these cases it is necessary to clean the filtering filling. For the cleaning of filtering filling it is necessary to open up the dryer or drain and remove the silted layer. The removed silted layer is washed and replaced. Then on the surface of the newly filled-in trench we place slabs of sod and level the adjacent



sections. Work on the cleaning of filtering filling and trench filling should be performed with great thoroughness, in order to provide aircraft flight safety on the sections being repaired.

The troubles of sewers, manholes and thalweg wells should be corrected immediately for the prevention of large failures. Broken gratings, broken covers, broken or dislodged elements of covers and pipe ends are replaced with new. Cracks on the walls and bottom of wells are preliminarily cleaned of dirt and dried, after which they are filled up with bitumen. With the presence of ground water the sealing of cracks is accomplished by quick-setting cement mortar.

Damaged couplings of pipes with wells are restored by driving tarred hemp into the clearance between the pipes and walls of wells and by filling by bitumen. The clearances between the walls of sewers and gutter slabs are filled with bitumen strictly flush with the surface of coverings. This is necessary to provide standard conditions of movement of water in the concrete gutters.

For the elimination of erosion and sags around the thalweg wells it is necessary to remove the washed away soil, add new and restore the mound around the wells.

Cracks and slits in drain pipes of large diameter are sealed from inside by cement mortar or bitumen. Small-diameter pipes, and also large-diameter pipes with large cracks must be replaced. The pipes are moved when there are considerable settlements of sections. For the replacement of faulty pipes at the places of damages we remove the sod in strips and dig up the pipes. Then we remove the damaged pipes and if necessary repair or reconstruct the bases. At the place of damaged pipes we install sound pipes of the same construction, the joints are sealed and the trench is filled with the earlier removed soil. The trench must be filled in layers with watering and thorough tamping. The

surface of the newly filled trench is covered with strips of sod and packed.

The damaged pipes of drainage channels and drains are repaired in the same order, but the joints are not sealed. It is advantageous to wash the filtering material in this case before filling. The method of repair of damaged joints is accomplished depending on the construction of the pipelines. It is advantageous to seal the joints of flared pipes with cement mortar. For this  $\frac{1}{3}$  of the butting space is packed with resinous strand moistened in cement grout and thoroughly tamped. Then the remaining gap is filled with cement mortar of 1:2 composition and caulked. During the repair of butt joints in water-saturated soils the joint being repaired should be protected from the inflow of water and after sealing with cement covered with a tarpaulin in order to eliminate crumbling of the unset mortar. The smooth unflaired joints of concrete and reinforced-concrete pipes are sealed with cement bands or bands made of ruberoid and borulin, stuck on the joint with bituminous cement.

For the sealing of joints with cement on the pipe we install a wooden casing and the seams for joining the casing to the walls of pipes are thoroughly coated with rich clay. In the upper part of the form we leave an opening, into which is poured cement mortar of composition 1:2. During the sealing of joints with strips of ruberoid or borulin the ends of the pipes are preliminarily cleaned of contamination, dried and greased with bitumen. Then we apply a layer of hot mastic and stick the strip of ruberoid or borulin 20-25 cm wide around the pipe. To the strip on hot mastic we stick an additional one-two layers of ruberoid or borulin.

With damage of the butt joints of asbestos-cement pipes there are installed sound asbestos-cement pipes with rubber rings.

In the case of the appearance of erosion and landslides of soils in high and drain channels, around inlet and outlet pipe ends it is necessary to remove the washed away soil and to fasten the damaged section by strips of sod, rods, brushwood or stone flooring.

With swelling soils there can occur breakaway of the pipe end from the pipe casing. To avoid damage of the pipe end, capable of causing backup of the water in the drain and sewer pipes, all damages of pipe ends should be completely removed. With considerable damages the pipe ends are reconstructed.

The maintenance and repair of surface-drainage networks is performed by the airport service. To the service is entrusted routine inspection of all surface-drainage networks with the elimination of malfunctions; control of maintenance of networks; cleaning of the network, the removal of contamination and the elimination of accidents; the routine repair of the surface-drainage network. In the airport service there should be located all the technical documentation of the surface-drainage network, including the working drawings of all systems and constructions. This service conducts planning and the account of measures for heavy repair of the surface-drainage networks, being performed by special repair and construction organizations.

Work on the repair of surface-drainage networks is performed directly on the flight zone of the airfield. To provide uninterrupted operation of the airfield the work on the repair of the surface-drainage network should be accomplished with minimum expenditure of time and as much as possible at night, when the aircraft traffic volume is decreased. For shortening of the periods of operational and repair work one should make wider use of mechanisms. For breaking up the concrete covering of gutter slabs a pneumatic tool is used, during the cleaning and repair of gutter slabs sandblasting machines are used. For the restoration

of joints in gutter slabs we use funnels and portable tanks for the pouring of mastic into seams. For working with bitumen when sealing broken seams, cracks and holes in the constructions of surface-drainage network we use the appropriate mechanized tools and equipment, which are used during the repair of black airfield coverings.

The packing of piled soil in trenches and on the surface is accomplished by pneumatic tampers and rollers.

To provide for high quality of repair of the surface-drainage network it is necessary to give serious attention to the control and acceptance of work. During the repair of gutter slabs with the placement of cast-in-situ concrete it is necessary to control the composition of concrete: it should have strength not lower than the strength of the concrete of the old covering. It is necessary to give special attention to the control of packing of the draining material during the repair of open gutters, located at the edges of coverings, and also during the filling of trenches after the repair of pipelines. Also no less important is the control of the provision of reliable sealing of the drain systems.

After completion of the repair work the drain lines should be checked for airtightness. The airtightness of pipelines is checked by inspection and filling of the system with water. The drain system filled with water should not have water leaks. For the acceptance of work on the repair of the surface-drainage network a commission is designated. During the acceptance of work the commission establishes their conformity to the approved plan, determines the quality of the work and compiles the certificate of acceptance of the completed work. In the certificate the commission indicates the name, quantity and periods of the completed work, the types and quantity of the materials used up. The approved certificate of acceptance of work is kept in the operational subdivision.

During the repair of the surface-drainage network there are used organic materials - bitumen, gasoline, kerosene, which constitute a hazard to the workers. To this one should add that repair of the elements of the surface-drainage network is performed in sunken wells and open trenches, in which with the unreliable securing of walls collapses can occur. All this imposes rigid requirements on the observance of safety technology. Safety regulations prescribe the provision of overalls for workers, instruction and training in the correct safe procedures of work. With lowering into a well the workers should have a protective belt with a cord attached to it. Above the well there should be one-two more man for observation and rendering help if necessary to the men working below. During the inspection of sewers the workers are also supplied with a protective belt with a cord attached to it. The gang working in the sewer should consist of four-five men and during the inspection of the sewer it is compulsory to be located in adjacent manholes and to keep in touch with the workers inspecting the pipes.

During the work on cleaning and repair of the surface-drainage network the drying of overalls or their replacement should be organized. The maintenance crew is supplied with a first-aid kit. Each worker should be given written instruction on the safe and correct production of work and the use of mechanical tools and equipment.

## CHAPTER XXII

### THE ORGANIZATION OF WORK ON AIRFIELD MAINTENANCE IN THE WARM SEASON

#### § 90. THE MAIN PROBLEMS OF ROUTINE MAINTENANCE OF THE AIRFIELD. THE PERIODS AND SEQUENCE OF THE TECHNICAL INSPECTION OF CONSTRUCTIONS

The main problems of routine maintenance - the provision of constant readiness of the airfield for flights of aircraft and increase of the service life of the entire complex of engineering constructions. This is attained by its correct operation, by systematic care and maintenance of the RW and dirt part of the flying field, RD, MS of aircraft, surface-drainage systems, interairport roads, access routes and airfield structures. The correct operation of the airfield provides for its use only for the established types of aircraft, the observance of a certain order of aircraft taxiing and motion of transport and special vehicles, the planning of flights taking into account the time necessary for the routine maintenance of the dirt part of the flying field, RW and airfield structures.

To provide for correct airfield operation maintenance technical personnel should know the constructions of structures, routinely take preventive measures for the preservation of structures, and in the necessary cases do the repair work for the elimination of the revealed defects. Of great significance for the revealing

of defects and the performance of maintenance is routine technical inspection of the airfield structures. The airfield structures of the flight zone are subject to technical inspection 2 times per year - in spring and in autumn. The remaining airfield structures of the service zone, intended for serving the transport and operational activity of the airport, will be inspected 1 time per year - in spring. The newly constructed or major repaired structures of the service zone will be subject to technical inspection 2 times in the first two years - in spring and in autumn. After two-year operation these structures will be inspected only once per year - in spring. For conducting the technical inspection there is designated a commission, which examines in detail the airfield structures and compiles a report of defects. It includes the types of trouble, their volume, periods of removal.

The revealed troubles of airfield structures must be removed in the proper time. The systematic work on the routine maintenance of the airfield increases its service life. The warm season is the best period for performing preventive measures and organization of work on airfield maintenance. During this period the routine repair of elements of the flying field, access routes, airfield structures is facilitated, on which the uninterrupted operation of the airfield in the spring and autumnal bad road periods and during the winter period much depends. The taking of measures during the warm period for the timely preparation for the work of airfield-operational technology in the different seasons and especially in winter has great significance. The successful accomplishing of all the enumerated measures facilitates the organization and the planning of work.

#### § 91. SPRING WORK

In spring there are taken a complex of measures for maintaining the airfield constructions of the flight zone in working order:

RW, RD, MS of aircraft and surface-drainage systems. No less important during this period is the maintenance of interairport roads and access roads. In spring in the northern and central areas of the country during the thawing period of the soil there occurs the greatest moistening of soil bases and constructive layers, decreasing the strength of coverings. Therefore the spring work on airfield maintenance is reduced mainly to the preservation of ground bases and artificial coverings of airfields and roads from the penetration of water and to its removal.

In spring we mainly remove the snow from artificial coverings, ensure the correct operation of surface-drainage systems of airport coverings and drain systems of interairport roads and access roads. The admission of spring water and floating ice through the artificial constructions of access roads has great significance.

Spring work also includes the acceleration of the suitability of dirt flying strips for their operation. A detailed description and the sequence of work on the maintenance of artificial coverings, surface-drainage networks of airfields, and also automobile and railroad access roads during the various periods of the year, including in spring, are given in the corresponding sections of the book.

The maintenance of the unpaved part of the flying field consists of the timely removal of water from closed low places, in order not to allow its prolonged standing on the surface, and consequently, the severe overwetting of soil. As the soil dries out we fill up the tracks and add dry soil to the low sections with packing by light pneumatic rubber rollers. If on the flying field there were formed sections of overmoistened soil having insufficient bearing capacity, it is necessary to reinforce them. In these cases there is used portland cement of



brand 400-500, ground caustic lime and their mixture is 1:1 ratio. For the reinforcement of overmoistened soils the following consumption of binding agent is recommended: cement 12-15 kg/cm<sup>2</sup>; ground caustic lime 10-18 kg/cm<sup>2</sup>; mixture of cement with lime 12-22 kg/cm<sup>2</sup>. For the reinforcement of overmoistened sections of the flying field it is necessary to remove the damaged layer of sod, seal the tracks and ruts with dry soil, introduce binding materials and mix them with the soil: then plane and pack the soil with rollers.

The operation of the unpaved part of the flying field, including the reinforced overmoistened sections, is possible when its bearing capacity will allow safe aircraft movement. Spring work on the maintenance of airfields, not having artificial RW, consists of preparation of a special strip, from which flights are performed, after the removal of snow cover and drying out of soil. For acceleration of the thawing of snow and drying out of soil the spring strips are located on the southern slopes of watersheds, selecting as much as possible the sections with well draining sandy soils. At the end of spring, when the soil gets dry, we fix the damages of the unpaved part of the flying field and surface-drainage networks.

By the airfield constructions of the service zone in spring the following measures are taken: water is drained from foundations and walls, roofs, drain pipes are cleaned from snow and ice, areas at constructions are put into order by filling up rain rills and pits, framework around buildings is restored, whitewash and paint are renewed, the disrepairs of engineering networks - water-conducting, channeling and others are inspected and removed.

## § 92. SUMMER WORK

The summer work at the airfields includes: the sealing of tracks and ruts, the addition and planing of soil on the unpaved

part of the flying field, care of artificial coverings and surface-drainage network, putting into order the interairport roads and access roads, the combatting of dust and contamination.

The summer period is the most favorable for the maintenance of artificial coverings of the airfield and highways. In the summer it is required to give special attention to the maintenance of nonrigid coverings. The coverings, constructed from materials treated with binding agent, are softened in hot weather: binding agent at places of excess sticks out on the surface of covering, the safety of takeoff and landing is disturbed. Therefore at places with excess binding agent it is necessary to throw on fines.

The control of dust and contamination is especially important. Dust increases the wear of friction parts of aircraft, impairs engine operation, and makes the landing of aircraft dangerous. Contamination and various metallic objects cause damages to the tires of aircraft. In dry and hot periods the coverings are wet down and washed with water. Foreign objects are removed from artificial coverings with special machines. For maintaining the airfield and access roads in constant year-round readiness and operation the timely preparation of airfield operational technology has great significance. Contemporary airfield operational technology represents an involved complex of machines intended for the maintenance and routine repair of the airfield. This complex includes includes snow-removal and snow-packing machines, machines for the removal of glare ice and ice from the artificial coverings, combined street-sprinkling and washing machines with snow plows, pneumatic rubber rollers, mechanisms for the repair of artificial coverings and others. In the summer the organization of preventive maintenance and routine repair by this airfield operational technology is the most advisable.

The complex of operations for airfield maintenance in summer also includes the removal of the dead residue of vegetation and the mowing of grass on the dirt part of the flying field and care of forest-plantations. The care of forest-plantations should be systematic and thorough. The work of care of plantations includes their weeding and the loosening of soil, the filling of empty places of upset trees and the clipping of hedges. It is recommended to perform weeding 4-5 times in the first year, in the second 3-4, in the third 2-3 and in the fourth 1-2 times. For loosening the soil and the removal of weeds between rows we use cultivators and hoes.

The filling of empty places of upset trees is performed on areas damaged by completely whole sections, by new replenishment, planted in holes under a shovel. The clipping of hedges is performed early when the top shoots reach thickness 3-5 cm. The cutting of branches is produced if they are not thicker than 5 cm for spruce and 8-10 cm for hardwoods. If necessary the young stands are tied up to installed stakes, and wet in the dry period. Forest-plantations need protection against felling and breaks, damage by cattle, damage with the visit of the different agricultural technology used during the work on adjacent fields.

### § 93. AUTUMN WORK

In autumn the airfield is under adverse conditions. The considerable amount of precipitation characteristic for this period leads to the overmoistering of soils on the flying field of the airfield and to a deterioration in the conditions of maintenance of artificial coverings on RW, RD and MS of aircraft. The overmoistened sections of the unpaved part of the flying field lose bearing capacity, and hamper aircraft motion. On artificial coverings there appears contamination, reducing the sticking of the aircraft wheels with the covering, which represents danger during takeoffs and landings. The autumn work includes

measures for the provision of normal operating conditions of the flying field and artificial coverings. Simultaneously in autumn the preparation of the airfield for winter is completed.

The autumn work on the unpaved part of the flying field is reduced to the acceleration of runoff and removal of water from the surface. This is attained by systematic care of the flying field, not allowing the formation of standing water on the surface, by the sealing of tracks, ruts. If necessary there is performed the selective reinforcement of defects by binding materials. Of great significance during this period is the correct organization of the movement of aircraft and automobiles. On airfields, not having RW with artificial coverings, for the prevention of failures of the soil it is necessary to systematically change the places of aircraft takeoff. These sections of the flying field, which undergo the greatest wear during the autumn period, it is advantageous to reinforce with binding agent or place temporary artificial coverings.

The main autumn work on the maintenance of artificial RW, RD, and MS includes the cleaning of coverings from dust and dirt, maintenance of the drain system, the covering of openings of sewer, thalweg wells and pipes in the areas with stable snow cover by mats or panels of planks or other material. Special attention must be focused on the maintenance of improved and simplified coverings. The defective sections of coverings (tracks, ruts, minor depressions and others) must be repaired at the proper time. It is necessary in autumn to especially thoroughly provide the normal runoff of surface water from the coverings.

During the autumn period the airfield is prepared for winter. This includes the termination of repair work on the flying field and on artificial coverings. In the unpaved part of the flying field the grass is mowed, the soil is graded and packed. All work on the repair of the dirt strip - the sealing of tracks, ruts, and

also work in the repair of artificial coverings - should be finished before the onset of autumn frosts and snowfalls. The drain systems are cleaned of silt and contamination, in order to provide the normal runoff of melt water during thaws and spring snow-melting. Special attention must be paid to preparation of the airfield structures for winter. Before frosts all repair and construction work should be finished, service yards put into order, the entrances to them prepared, the entrances to buildings warmed, and the glassing of windows finished.

Water-conducting, heat-conducting and channelization networks should be warmed. The equipment of summer water supply is drained of water and dismantled. The operation of central heating is checked and before the onset of cold the test heating of boilers is conducted and if necessary the discovered defects of boilers, heaters and pipelines are removed. Simultaneously the repair and preparation of the motor transport park and airfield operational equipment for winter are completed. For parking of machines and equipment for winter inspection of airfields heated locations are prepared. Before the formation of snow cover there are completed the procurement and delivery of the necessary construction materials for repair of airfield structures in spring to preplanned places. Preparation for winter is finished with the compilation of a plan for the winter operation of the airfield.

#### § 94. PROTECTION OF THE AIRFIELD FROM SHIFTING SANDS

Considerable areas, covered by shifting sands, are located in the zones of insufficient moisture. The principal areas of location of shifting sands are the deserts and semi-deserts of Central Asia, Caspian Steppes and Southern Transcaucasia. Considerably flat and humid sands are observed in the middle strip of Russia. In all the large deserts in the Soviet Union occupy about

300 million ha, which comprises approximately 14% of the area of the country. Sand is lifted under the action of wind; by encountering natural obstructions - hillocks, depressions and others, it is detained and blown out, forming various deposits, sweeps and hollows. We distinguish a number of sand deserts, being formed during the action of wind: barkhans, barkhan chains, sand ridges, sand hills.

Barkhans - sand hills from 0.5 to 10-12 m high (Fig. 119a). The windward sloping slope of barkhans has angle of slope 10-20°, and leeward - 33-35°. Barkhans are unstable and are easily shifted under the action of wind. The formation of barkhans is observed on smooth, exposed, flat surfaces with a small quantity of shifting sand.

Ridge sands are formed on a thick sand layer and have a characteristic form, elongated in the direction of the prevailing winds (Fig. 119b). In deserts, where the winter prevailing winds are opposite the summer, barkhan chains are formed (Fig. 119c). These chains are located perpendicular to the wind direction and have length up to several hundred meters, height up to 10-15 m and width 10-12 m. The sand hills - sand hillocks 6-8 m high, fastened by vegetation.

The quantity of the sand being transferred substantially increases with an increase of wind velocity. The shifting sands hamper the operation of the airfield, in a number of cases they lead to the termination of flights. The main means of protection of airfields from shifting sands are: the planting of protective tree-shrub strips; the sowing of perennial grasses - sand oats: the spraying of bituminous emulsion over the surface of sand.

The planting of strips of grass and shrubs along the perimeter of the airfield - the most reliable and lasting protection from

shifting sands. The tree-shrub strips retard the wind speed, fasten sand by a root system and connect the sand covering with vegetation deposits.

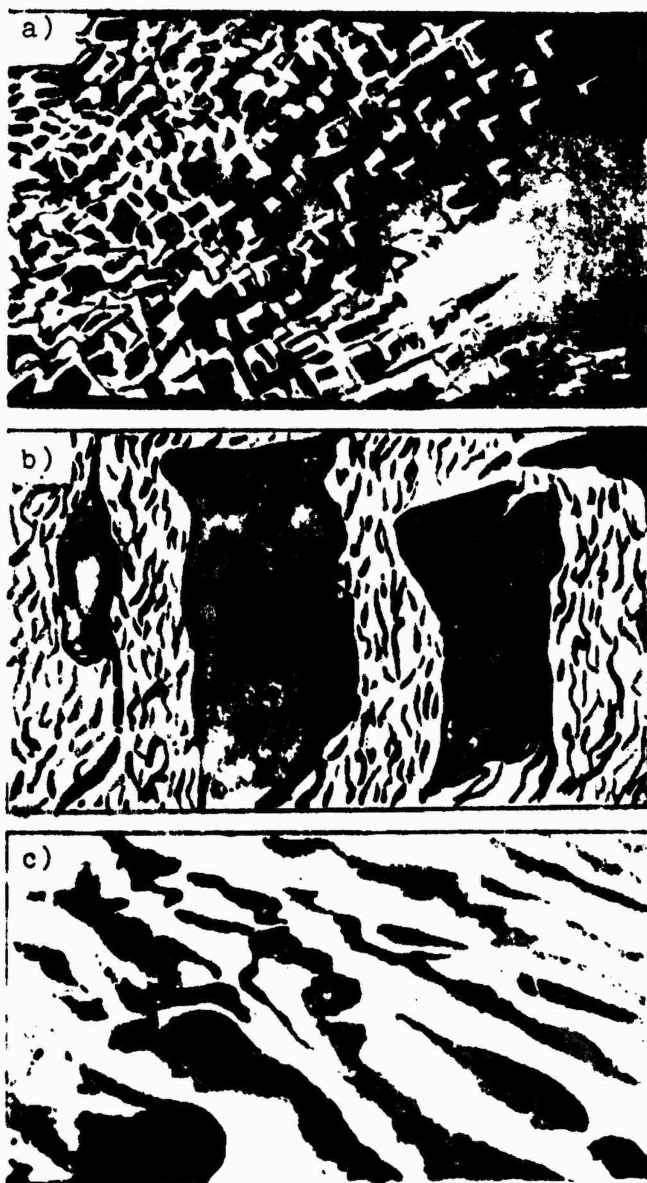


Fig. 119. Aerial photograph of sand deserts:  
a) barchan sands; b)  
ridge sands; c) barchan  
chains.

For reliable protection of the airfield from shifting sands the width of the tree-shrub strips on the windward side of the prevailing winds should be not less than 1000 m, and on the leeward side - 250 m. With the installation of such tree-shrub strips the

runways will not be accumulated with sands and they cannot be broken by them. Vegetation is planted only on smooth places and low places, sand on hillocks is preliminarily scattered through installed screens. With the fastening of sand by vegetation it is considered that in sand the quantity of nutrients is small and only certain forms of vegetation can grow in sand. Among them are local types of grass, scions of shrub and rhizome plants.

In a number of cases there are sown perennial grasses - sand oats. Sand oats make it possible to carry out rapid attachment of sand for a long time. Under a cover of oats the holding of sand is begun, which facilitates the development of grassy and shrub vegetation. The held sand, partially covered with vegetation, is not moved by the wind. The fastening of sand in the middle strip of Russia is put into practice by the planting of willow, which possesses a powerful root system. The roots are developed shallow under the surface of soil and fasten the sand. To avoid drying up it is necessary to cut the willows low every three-four years. For improvement of the protection of the airfield from sands during the subsequent years it is recommended to additionally plant trees and shrubs. During the fastening of sands with vegetation it is necessary to provide protection of the protective tree-shrub strips. It is not possible to allow the felling of stands, the grazing of cattle.

The creation of sufficiently dense tree-shrub strips requires several years. For saline and highly shifting sands with deep occurrence of ground water, the attachment with vegetation does not lead to satisfactory results. In such cases due to the insufficiently developed grassy and shrub vegetation the protective strips are torn up by the shifting sands, which fill in the airfield. Therefore along with the planting of protective tree-shrub strips the airfields are guarded by various types of solid barriers. With the installation of panels there appear vortex flows, leading



to the deposit of sand. We use solid and latticed panels. With the installed solid panels the deposit of sand occurs in front of the panels. If latticed panels are installed, the sand and wind flow, passing through the grids, decreases the wind speed, as a result of which the sand is deposited behind the panels. Latticed panels are more easily moved to a new place, since for their transfer it is not necessary to dig them up, which is necessary with solid panels. When the RW is located at an acute angle to the direction of the prevailing winds, instead of artificial protective strips we apply solid reflector panels. The sand and wind flow upon encountering solid panels is deflected and drifts along the shielding line.

We use panels of various construction: high, semi-hidden, hidden and spread-over (Fig. 120).

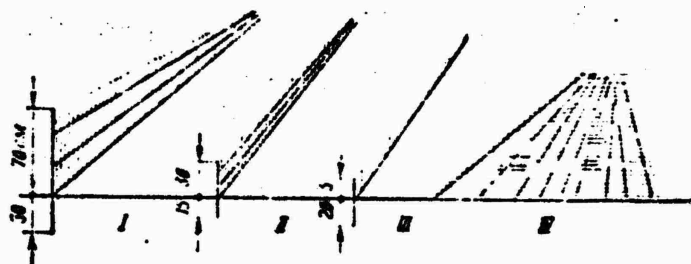


Fig. 120. The types of solid barriers:  
I - high, II - semi-hidden; III - hidden;  
IV - spread-over.

The panels are installed in several rows parallel to the runway and perpendicular to the direction of the prevailing winds.

In recent years along with the installation of vegetation strips for protection of the airfields from shifting sands there is used the surface treatment of sand with organic binding agents. Thus, according to the suggestion of N. Banasevich and N. Zakharov on the surface of sand there is sprayed bituminous

emulsion, with which there is attained the temporary calming of sands, which creates conditions for the attachment and development of vegetation. Protection of the airfield from shifting sands is coupled with a number of difficulties: there occurs increased wear of the friction parts of tractors, trucks, construction machines; due to the high resistance of sandy soils to the motion of construction machines more powerful tractive means are necessary; the absence of water; the presence of high temperature requires special safety measures. The workers should be reliably protected from solar rays, on machines there are installed cabs and protective tarpaulins.

## CHAPTER XXIII

### WINTER MAINTENANCE OF AIRFIELDS

#### § 95. BASIC REQUIREMENTS FOR THE MAINTENANCE OF AIRFIELDS IN WINTER

In winter the airfield should be in suitable condition for operation. For this purpose work is performed on the removal and packing of snow on the flying strips and other elements of airfields, where the aircraft or other machines and mechanisms which operate at the airfield move or are serviced. Furthermore, it is necessary to provide for preventive measures against the formation of glare ice on coverings or for a reduction of their slipperiness. In order to correctly be prepared for operation of the airfield, it is necessary in winter to know in advance the features of snowfalls in a given area, their expected intensity and the total probable quantity of snow that will fall during the winter period. Of great significance are the features of relief in the airfield zone and the most frequently being repeated wind velocity and direction. These data in general form are usually located in climatological handbooks, but the most reliable will be data obtained on the basis of the statistical processing of many-year observations directly at a given airfield. The same pertains to the frequency of recurrence and the expected intensity of glazed ice formations on the artificial coverings of a given airfield.

Therefore the main requirements for the maintenance of airfields in winter time include:

the correct forecasting of those conditions which are established at a given airfield in winter under the influence of climatic factors and features of its relief. This will make it possible to correctly determine the quantity of the necessary means of mechanization and special materials, required for maintaining the airfield in constant readiness for the execution of flights;

careful preparation of the airfield for winter in autumn before the onset of steady frosts for the protection of the airfield constructions from damage and to provide for the effectiveness of performing winter operational measures.

The experience of the winter operation of airfields shows that in winter it is necessary to clean of snow: RW, RD, MS of aircraft and the ramps, which have artificial coverings; unpaved flying strips and RD on airfields in areas with unstable negative air temperatures.

It is advantageous to pack snow: on unpaved RW, RD and MS on airfields in areas with stable negative air temperatures; on spare RW and side safety bands of the main and spare RW; on RD to spare strips and planed coupled cleaned and packed strips.

The method of maintenance of the airfields in the winter-spring period, and also the dimensions of the cleaned and packed areas are established with consideration of the class and purpose of the airfield and the climatic features of the area of its location.

For each airfield we compile the plan of winter maintenance, which provides for bringing the airfield in a short period to the

condition suitable for operation with the least expenditures of forces and means. The plan is a diagram of the airfield with indication of the cleaned and packed areas, places of spreading of snow and places of installation of snow-fence barriers. A component of the plan is flow charts (diagrams) of the production of work on the removal and packing of snow with indication of the order of use of machines and other mechanization means. The plan should provide for the rational use of forces and means of the operational unit servicing the airfield, the distribution of individual sections and types of work between crews; in it is provided the timing on the removal and packing of snow. It is recommended to compile the plan in two versions; for the average snowfall and maximum snowfall with possible drifts.

When developing the plan for the organization of work on the removal and packing of snow we provide for such a sequence of work, with which there is ensured the possibility of sudden or forced landing of aircraft.

Before the beginning of winter operation of the airfield it is necessary: to finish the repair of the flying field and artificial coverings of RW, RD, MS and the ramp; before the freezing of soil to mow grass, seal tracks and ruts, grade and pack the soil to the required density on the unpaved part of the flying field; to clean the drainage network from silt and contamination, to cover the water-inlet openings with mats or panels from planks, fastened on the bottom to the grates of water intakes; to clean the drainage ditches; to repair the approach and interairport roads and bridges; to repair and prepare the constructions of the service and technical site; to repair the machines and mechanisms utilized for winter operation of the airfield; to prepare heated locations for the parking of tractors and machines, to equip water and oil heaters, to manufacture lacking towing mechanisms, attachments and tools; to compile the plan for winter operation of the airfield; to assign the RW axes relative to fixed reference points,

to designate the boundaries of RW, RD and MS, to designate the water-intake manholes and the mouths of sewers, and also the boundaries of the cleaned and packed areas by cones, pyramids and stakes; to store the necessary building materials for the routine repair of airfield structures during the spring period; to train the personnel of airfield operational units on airfield maintenance during the winter and spring periods and operating regulations of airport machines and mechanisms.

#### § 96. ORGANIZATION OF THE WORK WHEN CLEANING THE COVERINGS OF SNOW

The cleaning of snow is the most reliable method of maintaining the airfield in constant readiness.

On RW, RD, MS and ramps with reinforced-concrete, concrete and asphalt coverings the snow is completely removed. If on the airfield at the moment of the beginning of snowfall there are no flights and according to the forecast no icing is expected, the cleaning of artificial coverings begins with the beginning of snowfall.

In areas with steady negative air temperatures with metal, simplified coverings and unpaved takeoff areas the snow is removed taking into account leaving on them a packed layer of snow not more than 5 cm thick. When cleaning metal coverings the steel knives of the plow blades should be replaced with rubber plates.

The organization of work on the removal of snow depends upon the dimensions of the area being cleaned, thickness and density of snow, velocity and direction of wind, and also the presence of snow-removal machines.

With snow cover up to 5 cm thick the snow is removed by snow plows on the whole width of the areas being cleaned. From the longitudinal axis to the side safety strips the snow is removed

by circular passes of the snow plows until the formation of longitudinal banks on the whole length of the area being cleaned. The snow moved to the longitudinal edges of the strip should be moved as fast as possible (before its freezing in the banks) to the places of spreading by rotary snow removers, where it is immediately levelled, and then packed by smoothers and rollers.

The cleaning of the RW of snow more than 5 cm high is produced by the combined work of snow plows and rotary snow removers (Fig. 121). By circular passes of the snow plows the snow is moved from the axis to the two longitudinal edges of the flying strip to the formation of the bank, which is not further moved by the plow blades, whereupon the snow from banks is moved to the shoulders of the RW by rotary snow removers.

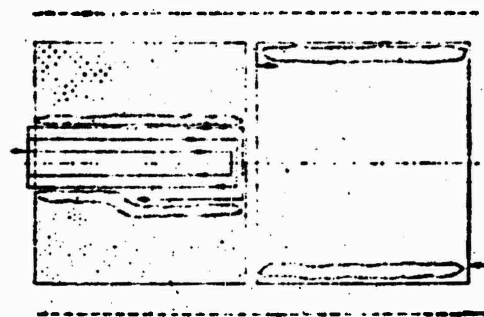


Fig. 121. Diagram of cleaning the snow from the RW by the combined work of KPM and rotary snow removers.

The maximum possible width of the strips being cleaned, on which by circular passes of KPM-1 or KPM-2 there are created snow banks of limiting size, depending on the thickness of the layer of snow and its density is determined from the graph (Fig. 122), where each curve of the graph corresponds to a certain snow density. For example, with thickness of snow 6 cm and its density  $0.15 \text{ g/cm}^3$  on the graph the maximum width of the strip being cleaned by KPM machines is equal to 60 m (during the work by circular passes from the axis to both sides 30 m each).

By the alternation of work of snow plows and rotary snow removers there occurs full cleaning of the RW to the required width. The final removal of snow after the snow plows is accomplished by the sweeping of the coverings with the brushes of the KPM machines.

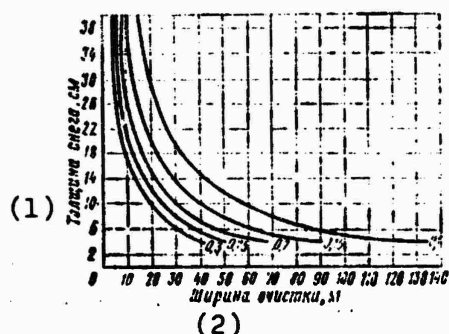


Fig. 122. The graph of the maximum width of the strip being cleaned of snow by KPM-1 machines depending on the thickness of the layer of snow and its density.

KEY: (1) Thickness of snow, cm; (2) Width of cleaning, m.

With the magnitude of cross component of wind velocity, perpendicular to the longitudinal axis of the RW up to 8-10 m/s, the area being cleaned in width is divided into two unequal parts. The magnitude of displacement of the axis of the beginning of work in the direction opposite the direction of wind velocity is taken from the graph shown on Fig. 123. By the combined work of snow plows and rotary snow removers the greater part of the width of strip is cleaned of snow in the direction of wind, smaller - against the wind (Fig. 124).

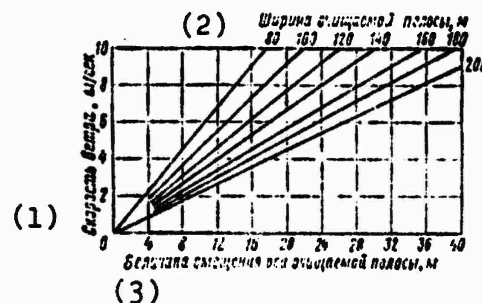


Fig. 123. The magnitude of displacement of the longitudinal axis of the strip depending on wind velocity.

KEY: (1) Wind velocity, m/s; (2) Width of the strip being cleaned, m; (3) Magnitude of displacement of the axis of the strip being cleaned, m.

With the magnitude of cross component of wind velocity perpendicular to the longitudinal axis of the RW 10 m/s and more, and thickness of snow up to 15 cm the runway is cleaned of snow in the direction of the wind. The work begins from the longitudinal edge of the runway, opposite the place of lining of snow (Fig. 125).

The empty pass of snow plows and rotary snow removers is eliminated by turning the plow blades and the volute chamber of the rotor at the end of each working pass.



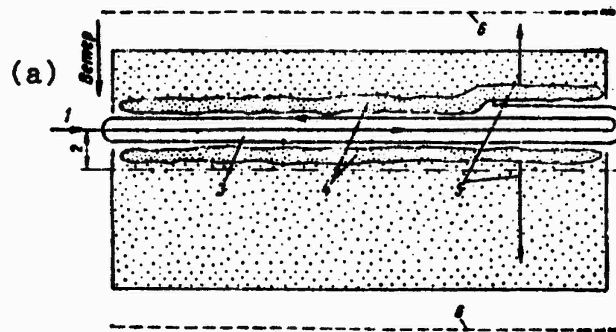


Fig. 124. Diagram of cleaning the strip from snow with velocity of cross wind 8-10 m/s: 1 - position of axis of beginning of work; 2 - magnitude of displacement of the axis of the strip being cleaned; 3 - work of snow plows and rotary snow removers; 4 - banks; 5 - direction of the transfer of snow by rotary snow removers; 6 - place of lining of snow.

KEY: (a) Wind.

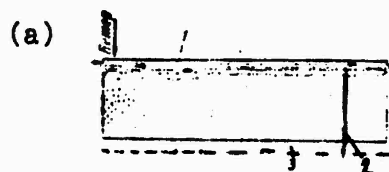


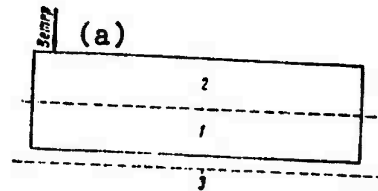
Fig. 125. Diagram of cleaning the snow from the strip at crosswind velocity 10 m/s and more: 1 - work of snow plows and rotary snow removers; 2 - the direction of transfer of snow by rotary snow removers; 3 - place of lining of snow.

KEY: (a) Wind.

The cleaning of the RW from snow of high density and a high layer more than 20 cm at crosswind velocity more than 10 m/s is performed in one direction downwind, whereupon the strip being cleaned is divided in width into two equal parts. Initially we clean the second half of the RW (Fig. 126), and then repeatedly clean the first half.

When cleaning the RW from snow with high layer over 20 cm and density more than  $0.3 \text{ g/cm}^3$  and in the absence of wind for shortening of cleaning the RW in width is divided into four parts. The displacement of snow by snow plows and rotary snow removers is accomplished simultaneously from the extreme one-fourth to shoulders and from the middle to the edge through the cleaned extreme one-fourth of the strips.

Fig. 126. Diagram of cleaning of the strip from snow of high height and density with velocity of cross wind 10 m/s and more: 1 - the first half of cleaning; 2 - the second half of cleaning; 3 - the place of lining of snow.  
KEY: (a) Wind.



If machines of different types work on the cleaning of snow, then snow plows of all brands and rotary snow removers are primarily used in a common column on the RW, and the remaining means - on RD and MS of aircraft.

With large side slope of the locality adjacent to RW, creating danger of flooding of the RW during the snow-melting period, the snow is lined on the one lowest side. In the case of removal of snow by truck it is lined in low places.

During the maintenance of RW equipped with signalling means, it is necessary to consider the following peculiarities: the places of installation of runway lights should be designated by well noticeable reference points; the removal of snow around runway lights in a diameter of 3-4 m should be accomplished by small-size MS-59 rotary snow removers or by T-3 snow plows; when the runway is equipped with portable lights it is necessary to pay attention to the safety of the cable.

As reference points during the designation of the location of runway lights there can be used cones with dimension at the base 50 cm and with height not less than 40 cm, painted red or black, flags with height of pole 0.5 m or fir-tree branches. For easing the work of snow removal under night-time conditions the system of runway lights should be turned on.

In areas with a large quantity of snowstorms and drifting snows for the protection of RW, RD, MS from snowdrifts we install

portable panels or construct snow banks at a distance of 50-70 m from the side safety strips, 30-40 m from the edge of RD and MS. Latticed panels 1.5 m high and 2 m wide from thin planks with the area of clearances 50-75% of the area of the panel are installed vertically with the aid of stakes. Panels are installed end-to-end or in groups of 10-15 panels in several rows in checkerboard fashion with the distance between rows and groups of panels 25-30 m. With the deposit of snow at the panels at 0.5-0.75 of their height the panels are raised to the top of the snowdrifts. Snow banks 50-60 cm high are created by snow plows, grader or by angle plate. Banks or snow walls are constructed in 2-3 rows parallel to the shoulders and are restored in proportion to their drift. For a decrease of drifts aircraft on the MS should be placed with the nose towards the direction of the prevailing winter winds. The surface of the packed snow on RW, RD, MS and at the places of lining of snow in order to avoid drifts is levelled by smoothers and graders both during snowfall and after its termination, but not later than 1-2 h, i.e., before freezing and hardening of snow. The coupling of RW and RD, being cleaned of snow, with the packed snow cover, and also with the places of lining of snow, should have slope not more than 1:15.

#### § 97. THE PACKING OF SNOW COVER ON THE AIRFIELD

The packing of snow on the airfield should provide for the creation of a snow covering with a bearing capacity which ensures the possibility of takeoffs and landings. The snow is packed by smoothers with specific pressure  $0.5-1.0 \text{ kgf/cm}^2$  and towed rollers with specific pressure from 2.0 to  $6.0 \text{ kgf/cm}^2$ . Smoothers are used for the preliminary packing of the snow before the work of rollers or for smoothing the snow after packing by rollers. Smoothers should be used in a tractive connection of three pieces. Four types of towed rollers are used: wooden 4-ton, padded with roofing iron; metal 5-ton, stretched over with sheet rubber 2-5 mm thick for the prevention of the adhesion of snow; pneumatic rubber

D-219 (weighing 10 t) and D-263 (weighing 25 t); pneumatic rubber with controllable pressure in the tires from 3 to 6 kgf/cm<sup>2</sup> and weighing 12 t D-625 (and weighing 25 t) (D-703).

Pneumatic rubber rollers, which provide higher degree of compaction of the snow at considerably less passes of the rollers along one track, are the most effective. For the full use of the power of tractors light rollers should work in a tractive connection of three or five pieces. The organization of packing of snow on the RW should provide for accomplishing elliptic passes of the tractors with rollers over the entire length of the strip from the axis to shoulders, so that at any stage it would be possible to provide for the sudden landing of aircraft. Every subsequent pass of the unit of rollers should overlap the previous track by not less than 30 cm.

The packing of snow on the airfield should begin right after steady snow occurrence and be performed systematically after every snowfall and in the periods of thaws. The process of packing leads to an increase in the thermal conductivity of snow, causing the alignment of its temperature with the ambient temperature, as a result of which there occur the cooling and freezing of snow, thereby ensuring its hardening and increase in the bearing capacity of the snow covering.

The processes of cooling and rise of the strength of snow after packing proceed gradually and are finished in 2-4 h, therefore the intervals in time between the passes of packers should be minimum and not exceed 30 min. Exceeding the intervals can lead to the disturbance of the normal flow of the process of hardening of snow and in view of the absence of the packing effect - to the unproductive use of technology.

The quantity of passes of rollers along one track depends upon the effectiveness of the packing effect of the packers and

the physico-mechanical properties of snow, but should not exceed four. During the packing of freshly fallen snow with height of layer more than 10 cm it should first be settled by smoothers, and then without intervals in time be treated by rollers. During the packing of virgin snow with height of layer more than 20 cm, for the purpose of its uniform working with respect to thickness, first it should be loosened by tooth or disk harrows, whereupon without intervals in time it should be packed by smoothers and rollers.

All roughness, which appeared on RW and RD as a result of the movement of aircraft and special truck transport, is sealed and packed immediately after the execution of flights. The most damaged sections of the snow covering are sealed with delivered snow or corrected by transverse passes of snow pushers and rollers.

In the case of formation of an upper packed or ice crust with an underlying loose layer of snow on the snow covering, it is necessary to first break the crust with a cultivator, harrows or by spiked cylinders, after which the snow cover is packed by rollers and smoothed out by smoothers.

On the airfields, prepared by the method of the packing of snow, the suitability of the RW for takeoffs and landings is determined by the strength and smoothness of snow coverings. As the basic strength criteria of snow coverings there are the density and hardness of snow, the systematic monitoring of which is accomplished during the entire period of winter operation of the airfield. The smoothness of the surface of snow coverings on the RW of field airdromes is evaluated and checked just as on unpaved flying strips. The strength and smoothness of snow coverings are checked before flights, and also after the packing of freshly fallen snow and the performance of repair and restoration operations (the sealing of fields and roughness) on the flying field.

The strength of the snow covering depends upon the structure, degree of compaction and the temperature of snow; with temperature decrease the strength (hardness) of the snow increases, and with increase - it is lowered. In practice the snow density does not depend upon the temperature variations and remains constant in the layer of snow, which is not exposed to the action of packing means or operational loads. The density is measured along the axis of the RW on the start-finish sections with length 300 m every 50 m, and on the remaining part of the flying strip - every 200 m.

The snow density of the covering is determined by the ratio of the weight of the taken sample to its volume:

$$\rho = \frac{Q}{V}. \quad (92)$$

where  $\rho$  - the snow density, g/cm<sup>3</sup>;

$Q$  - weight of sample, g;

$V$  - volume of sample, cm<sup>3</sup>.

Under field conditions the snow density can be determined with the aid of lever-type or spring-type weight densitometer, and also indirectly by the melting of a sample of snow.

#### Determinining the Snow Density by Lever-Type Weight Densitometer

The densitometer (Fig. 127) is a metal cylinder 600 mm high with cross-sectional area 50 cm<sup>2</sup>, on the external surface of which there have been placed graduations every 1 cm. The lower cutting edge is sharpened. On the cylinder there is freely placed a ring with handle for suspending the cylinder from a steelyard. The cylinder is closed by a cover.

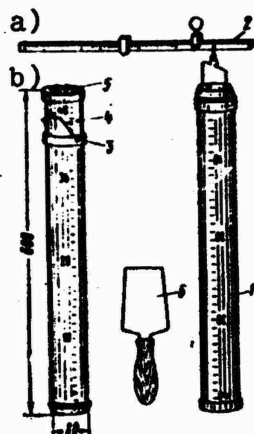


Fig. 127. Lever-type weight densitometer for snow: b) position when taking a sample; a) position when weighing the sample (densitometer inverted); 1 - cylinder; 2 - lever-type steelyard; 3 - ring; 4 - small wire arc; 5 - lid; 6 - knife-trowel.

The steelyard with a movable weight has graduations every 10 g. For sampling the cylinder with the cutting edge is placed vertically on the surface of snow and by pressure or by the blows of a hammer is driven into the soil or ice.

By the graduations of the housing of the cylinder we determine the thickness of the snow covering, with a knife-trowel we undercut the snow under the cylinder, which is then tipped and hung on the steelyard for determining the weight of the sample of snow.

The density of the sample of snow is determined by formula

$$\rho = \frac{Q}{hF}; \quad (93)$$

where Q - the weight of the sample of snow, g;

h - the thickness of snow cover, cm;

F - the cross-sectional area of the cylinder, cm<sup>2</sup>.

# Determining the Density of the Snow with a Spring-type Portable Densitometer

The portable spring-type densitometer (Fig. 128) consists of a housing, spring, scale and measuring beaker. The instrument scale is calibrated every 10 g with a suspended measuring beaker.

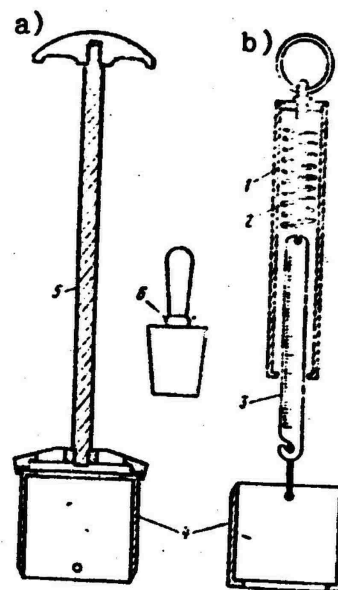


Fig. 128. Portable spring weight densitometer for snow: a) sampler with measuring beaker; b) the spring balance with measuring beaker; 1 - housing; 2 - spring; 3 - scale; 4 - measuring beaker; 5 - sampler; 6 - knife-trowel.

A special metal sampler and also a metal knife-trowel and wooden mallet serve for convenience in selecting samples from snow covers.

The housing of the densitometer is made from a duralumin tube with a diameter of 20-25 mm and with a length of 200-250 mm;



measuring scale - from a duralumin plate with a length of 120-150 mm, thickness of 1 mm, and with a width of 8-10 mm. An elastic spring of high quality steel, whose elongation should be 0.5-1 mm per 1 g of weight, is used for the densitometer.

The measuring beaker, with thickness of walls of 1.5-2 mm is made from duralumin; it has arc of steel wire with a diameter of 1 mm. The sampler with a length of 150 mm is made from steel with a diameter of 10-12 mm and has a head with a diameter of 30-50 mm and a supporting platform which should fit freely on the bottom of the measuring beaker.

The knife-trowel with a height of 150 mm and a width of 100 mm is made from sheet steel with a thickness of 1.5-2 mm, and the mallet - from hardwood.

The measurements of density are conducted in the following order:

- 1) on the investigated section of snow cover, with the knife-trowel we level out an area with dimensions  $0.2 \times 0.2$  m, in which regard the levelling of its surface is performed only by cutting the snow;

- 2) the wire arc is removed from the measuring beaker, whereupon the beaker is placed with the sharp edge on the levelled surface and through the sampler is buried in the snow by pressure or by taps of the mallet until the bottom of the beaker reaches the surface of the snow. The termination of the insertion of the beaker is checked through the opening in its bottom. During the sinking process it is necessary to see to the maintenance of the vertical position of the measuring beaker relative to the surface of the area;

3) the beaker with sample is dug in and carefully removed from the snow with the aid of the steel knife-trowel, and then is turned bottom up. The surface of the sample is levelled out flush with the cutting edges of the beaker with the knife.

4) the smaller arc is placed on measuring beaker after which the beaker with the sample is suspended from the scale of the spring balance and weighed.

The snow density is determined from the formula

$$\rho = \frac{Q}{V} . \quad (94)$$

where Q - the weight of sample determined according to the scale of the balance, g;

V - the volume of the sample of snow equal to the volume of the measuring beaker, cm<sup>3</sup>.

Periodically (2-3 times a month) a control testing of the readings of the scale of the spring balance is conducted, for which the measuring beaker is loaded with a set of weights of 10, 20, 30 ... 100 g. In the case of the nonconformity of the readings it is necessary to plot new divisions on the scale.

#### Determining the Snow Density by Melting the Sample

The method of melting the sample is most laborious and can be used only in the absence of densitometers.

For determining density of a sample of a specific volume ( $V_{\text{snow}}$ ) it is melted (usually indoors), after which with the use of a graduated cylinder or other measuring glass the volume of the water which has formed ( $V_{\text{water}}$ ) is determined.

The density of the sample of snow is determined by the ratio of the volume of water to the volume of the sample of the snow

$$\rho = \frac{V_{\text{water}}}{V_{\text{snow}}} \text{ g/cm}^3. \quad (95)$$

Between the density, temperature and hardness (strength) of the snow there is an interconnection which can be expressed by the empirical formula

$$\sigma_{\text{hardness}} = 8\sqrt{1+[t]}. \quad (96)$$

where  $\sigma_{\text{hardness}}$  - the hardness (strength) of the snow,  $\text{kg/cm}^2$ ;

$\rho$  - the snow density  $\text{g/cm}^3$

$[t]$  - the temperature of snow,  $^{\circ}\text{C}$ .

According to the measured density and temperature of the snow, with the aid of the formula presented above it is possible to determine the hardness (strength) of the snow surface.

Determination of the hardness (strength) of the snow covering from the density and temperature of the snow is accomplished with idled psychrometric thermometers (Fig. 129).

Measurements are performed every 500 m along the axis of the runway, in which regard the sensitive part of the thermometer should be placed at half the thickness of snow cover.

The hardness (strength) of the snow cover depends upon the density, temperature, structure and time of the formation of the snow in the covers. The hardness (strength) of the snow covers is measured after conducting repair and restoration operations and the levelling and packing of the freshly fallen snow, and also just before flights. Measurements are conducted every 100 m,

in which regard at every point they take three measurements and from them derive the average amount of hardnesses at each picket.

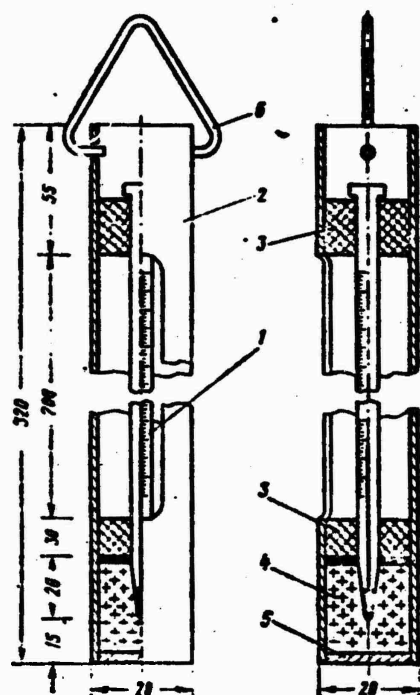


Fig. 129. Thermometer for measurement of the temperature of the snow: 1 - psychrometric thermometer; 2 - metal housing; 3 - paper ring; 4 - thermal insulation material; 5 - stopper.

The hardness (strength) of the snow covers can also be determined with the use of a conical hardness gauge (Fig. 130), the basic elements of which are a metal cone with an angle of  $34^{\circ}12'$ , which is impressed in the snow by a load from the weight of the observer 1, supporting platform for the foot 2, movable rod with supporting platform 3, and a scale of the depth of penetration of the cone 4 fastened to the housing 5.

The cone with a height of 100-120 mm is machined from steel or duralumin and, to lighten the weight is made hollow; the cone can also be made of wood and covered with sheet steel 1 mm thick.

The cone of the hardness gauge is made from boards or multilayer plywood 10 mm thick. The attachment of individual parts of the housing is accomplished with wood screws or pins.



Fig. 130. Conical hardness gauge.

In the creation of a load on the cone, it is impressed into the snow covering through the platform for the foot while the movable rod with supporting platform remains on the surface of the snow and the pointer - the rod's indicator - slides along the scale of housing from which the reading of the amount of penetration of the cone is performed. With the same load, the penetration depth of the cone is decreased with an increase in the hardness of the snow.

Numerically, hardness (strength) is conventionally equal to the ratio of the applied vertical load to the area of projection of the cone imprint measured at the level of the surface of the snow cover

$$\sigma_{\text{hardness}} = \frac{P}{F}, \quad (97)$$

where  $P$  - the load on cone, kgf;

$F$  - the area of projection of the cone imprint,  $\text{cm}^2$ .

Or expressing through the depth of penetration of the cone

$$\sigma_{\text{hardness}} = \frac{P}{\pi h^2 \lg \frac{\alpha}{2}}, \quad (98)$$

where  $h$  - the depth of penetration of the cone, cm;

$\alpha$  - the angle of taper of the cone.

The measurements of the hardness (strength) of snow covers are conducted in the following order:

- 1) on the investigated section of the snow cover we select a flat area  $30 \times 30$  cm, in the center of which the conical hardness gauge is installed;
- 2) with his left hand, the observer holds the housing of the hardness gauge in the vertical position and carefully stands with one foot on the supporting platform over the cone, transferring the weight of his body to it. The maintenance of the vertical position of the prop-support is checked with the aid of a plumb line;
- 3) after removing the load from the platform of the instrument the depth of penetration of the cone is determined from the scale graduated in centimeters;
- 4) according to data of the determinations of the depth of penetration of the cone, with the aid of Table 70 or the graph (Fig. 131) constructed from the data of this table we calculate the hardness (strength) of the upper layer of the snow cover ( $\sigma_{\text{hardness}}$  kgf/cm<sup>2</sup>).

The results of the measurements of the density, temperature and hardness (strength) of the snow are entered in a special journal. The sections on which the hardness (strength) of the snow cover is less than required are additionally packed.

The hardness (strength) of the snow covers is usually increased with time.

Table 70

Depth of penetration of the cone, cm	Hardness (strength) of snow, $\sigma_{\text{hardness}}$ kgf/cm <sup>2</sup>				
	With P = 60 kgf	With P = 65 kgf	With P = 70 kgf	With P = 75 kgf	With P = 80 kgf
3	22.40	24.20	26.10	28.00	29.80
4	12.60	13.60	14.70	15.70	16.75
5	8.05	8.72	9.40	10.05	10.70
6	5.60	6.05	6.53	7.00	7.45
7	4.10	4.45	4.80	5.13	5.47
8	3.15	3.40	3.67	3.93	4.20
9	2.49	2.69	2.90	3.10	3.31
10	2.01	2.18	2.35	2.52	2.68
11	1.66	1.79	1.94	2.08	2.22
12	1.40	1.50	1.63	1.75	1.86
13	1.19	1.28	1.39	1.49	1.59
14	1.03	1.10	1.20	1.28	1.37
15	0.90	0.96	1.04	1.12	1.19

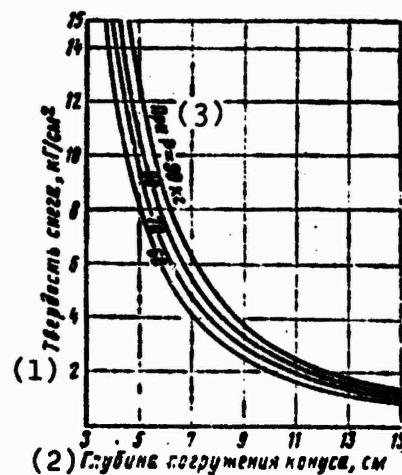


Fig. 131. Dependence of the depth of penetration of the cone on the hardness of snow.

KEY: (1) Hardness of snow, kgf/cm<sup>2</sup>; (2) The depth of penetration of the cone, cm; (3) With P = 90 kg.

**§ 98. THE REMOVAL OF THE CRUST ICE  
FROM SURFACES AND MEASURES FOR THE  
PREVENTION OF THEIR ICING**

When ice crust formations exist on airport surfaces the flight safety of modern aircraft is not ensured since they lose controllability during movement over ice-covered runways (RW), taxiways (RD) and parking places (MS), and the effectiveness of their brake systems is sharply reduced. Therefore, the flights of passenger aircraft on airfields coated with crust ice have been forbidden.

Crust ice formations on artificial airport surfaces are dense transparent glass-like crusts of ice which appear primarily as a result of the freezing of drops of supercooled rain, drizzle, or fog. Crust ice is usually formed with an air temperature of from 0 to  $-6^{\circ}\text{C}$ . The beginning of the formation of crust ice is noted with the relative humidity of the air of 94-100% and a wind up to 7 m/s. The duration of the forming of crust ice varies and fluctuates from 1 to 17 h and sometimes even more. Depending on the conditions for the formation of the crust ice, its thickness can fluctuate from 0.5 to 5 mm, and sometimes even more. Similar in their properties to crust ice crusts are the ice formations which appear with the freezing of the melted or fused snow, rime, or hoarfrost.

In winter time and especially during transition periods (at the end of autumn and in the beginning of spring) it is necessary to conduct preventive measures for the prevention of the formation of crust ice on artificial surfaces. A condition for the successful prevention of the formation of crust ice on artificial surfaces is the constant communication of the airport service with the weather station of airfield which should warn about the forthcoming crust ice in advance.



On all types of major airport surfaces it is necessary to conduct the preventive measures: to clean the snow from the runway completely to the surface of the artificial surface; to immediately remove the snow from artificial surfaces which falls with temperatures above zero; not to remove the dry snow from surfaces until the termination of wet precipitation with snowfalls under conditions of temperatures below zero with the expected transition of the snow into freezing rain; to remove the water from local depressions on artificial surfaces during the precipitation of rain with machines KPM-1 (KPM-2) with plow breasts equipped with cover plates of sheet rubber or other water sweepers; to prevent thaw water from getting on the artificial surfaces during the thawing period.

The heat method for the removal of crust ice formations is used on rigid airport surfaces. On asphalt-concrete and black surfaces it can be used only in exceptional cases with the impossibility of using the chemical method. The principle of the heat method consists of the effect, on the ice, of a heat flow which has high temperature and a large dynamic pressure which causes the melting of the ice and the blowing away of the formed water and residue of ice in the direction of the safety strips. The heat flow is created by a jet engine mounted on a T-105 (TM-57) or D-452 (TM-59) machine

During the period of possible precipitation of the super-cooled moisture it is necessary to organize the standby of the heat machines which, with the precipitation of moisture, dry the surfaces and prevent crust ice formations. With the expectation of a temperature decrease with passing through zero, the wet sections of the artificial surface must also be pre-dried with the use of the heat machines.

During the removal of crust ice formations from artificial surfaces with a heat machine, its motion should be parallel to

the longitudinal axes of the RW, MS and RD. The scheme for the movement of the heat machine is selected on the basis of the cross section of the artificial surface and wind direction and should ensure the best run-off of the water; with a two-slope cross section - by a ring-like scheme (Fig. 132a), beginning from the longitudinal axis of the RW; with a single-slope cross section - by a shuttle scheme, beginning from the side of the upper edge of the surface (Fig. 132b); with a strong wind (more than 10 m/s) along the longitudinal axis of the surface - downwind by parallel passes of the machines with idling in the opposite direction (Fig. 132c).

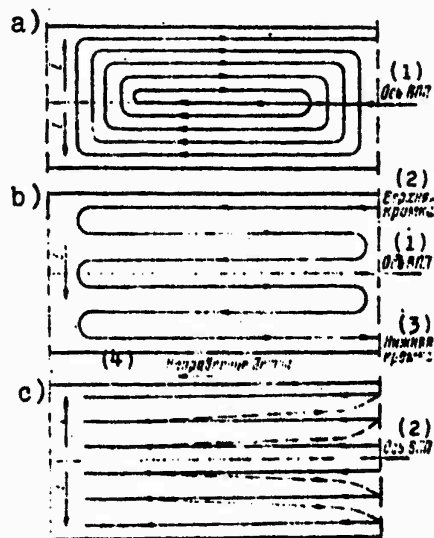


Fig. 132. Diagram of the movement of the heat machine during the removal of crust ice formations.  
KEY: (1) Axis of runway;  
(2) Upper edges; (3) Lower edge;  
(4) Wind direction.

During the simultaneous operation of several heat machines, their movement is organized according to the selected scheme by the "bearing" (staggered) formation with the distance between them 20-25 m and overlap of the strip being processed of 0.20-0.40 m. With the first pass of the heat machine (if several machines work simultaneously) on the leading machine the attachment of the jet engine is set along the axis of symmetry of the machine. With the subsequent passes of the machine (group

of machines) the attachment is set at an angle of 15-45° (depending on the thickness of the ice and the air temperature); in this, the smaller angle corresponds to a lower temperature. The heat machines are most expedient with the thickness of crust ice formations of up to 3 mm, and also independent of the thickness of the ice at an air temperature no lower than minus 10°C. With large thicknesses of ice and lower temperatures the productivity of the heat machine is considerably reduced. Productivity usually fluctuates from 0.5 to 0.85 hectares per hour. The operating speed of the heat machine is established by the operator and depends upon the thickness of the crust ice formation and air temperature. It should be that at which the formation of a dry surface is begun on the concrete surface.

When an ice coating exists on the surface with a thickness of 1-2 mm, the operating speed of the heat machine should be at least:

With the air temperature to -3°C .....	4 km/h
With the air temperature from -3 to -5°C .....	3 km/h
With the air temperature from -5 to -10°C..	1 + 2 km/h

It is necessary to see that during movement all wheels of the heat machine are on a surface cleared of ice. When using heat machines it is forbidden: to make long stops with operating jet engines on an artificial surface freed of ice; to work during a snow-fall since the snow, falling on the processed and warmed-up artificial surface, melts and can freeze, forming a crust of ice; to direct the jet of hot gases to the light-signal equipment of the airfield; to move with an operating engine over an artificial surface from which the ice has not been cleared.

For the prevention of ice crust formations on black and asphalt-concrete surfaces an aqueous solution of the chemical

reagent NKM is used. The systematic use of the reagent NKM for the prevention of the formation of crust ice and for the melting of ice on reinforced-concrete and cement-concrete airport surfaces is not recommended, since it damages the surface of the slabs.

The essence of the method consists of the fact that directly before the start of the crust ice an aqueous solution of the chemical reagent NKM is poured over the black or asphalt-concrete surface which, during the formation of crust ice, prevents the formation of a continuous layer of ice. The reagent NKM is a finely crystalline white powder and its volumetric weight in a loose state is  $0.65-0.75 \text{ g/cm}^3$ . Up to 55% the concentration, the reagent dissolves well in water at a temperature of  $+20^\circ\text{C}$ . The prevention of the formation of crust ice with aqueous solutions of the reagent NKM is accomplished at an air temperature no lower than  $-7^\circ\text{C}$ . The concentration of the aqueous solutions of the reagent NKM is taken depending on the air temperature. The aqueous solutions of the reagent NKM are prepared under field conditions by two methods.

The first method - with possibility of providing a sufficient quantity of warm water (for example from a heating plant boiler central) the powder-like reagent is dissolved in warm water directly in the tank of the KPM-1 (KPM-2) machine. The NKM reagent is poured into the tank, warm water is poured in whose temperature should be within limits of  $40-60^\circ\text{C}$ , the pump is switched to internal circulation, and during the movement of the machine from the servicing point (the boiler room) to the RW the complete dissolving of the reagent occurs. For the solution of the powder-like reagent NKM 4-6 min are necessary.

The second method - in the absence of warm water, the aqueous solution of the NKM reagent is prepared in advance. For this, in large containers (wooden or iron) a 50% solution is prepared by means of dissolving 1000 kg of the powder reagent NKM for each

1000 liters of warm water and then, depending on the air temperature, before its use it is diluted with cold water during the refilling of the KPM-1 (KPM-2) in the corresponding proportions.

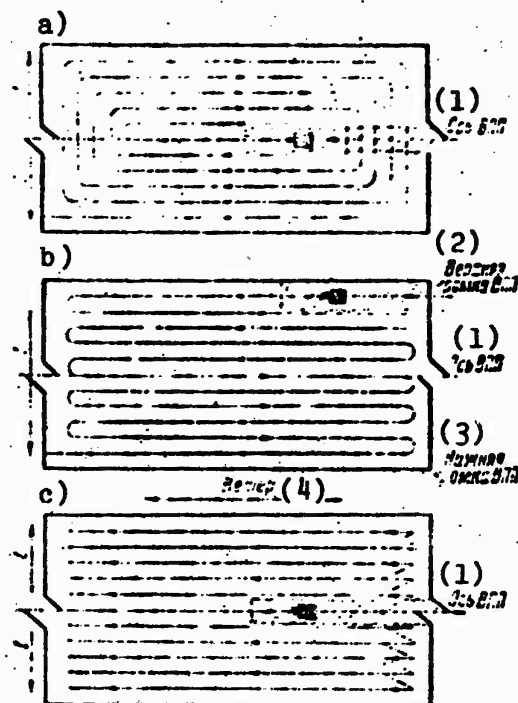
The concentrated solution of the reagent NKM is kept well in prolonged storage and does not freeze to a temperature of  $-19^{\circ}\text{C}$ . The norm of the spreading of the aqueous solution of reagent NKM is  $0.5 \text{ l/m}^2$  for one pass. The form for the spreading of the solution is adjusted during the period of the preparations of the KPM-1 (KPM-2) machine for winter operation by test spreadings of water. Knowing the quantity of expanded water and the area of spread, they attain (by changing the speed of movement discharge of the pump, the setting angle of the attachments) the calculated norm of expenditure -  $0.5 \text{ l/m}^2$ .

Recorded for each KPM-1 (KPM-2) machine is the speed of movement, pump discharge and setting angle of the attachment which are entered on a card and fastened in the drivers cab.

The selection of the scheme of movement of the KPM-1 (KPM-2) is influenced by the transverse cross section of the artificial surface and the direction and force of the wind. With calm weather or the coincidence of the wind direction with the longitudinal axis of the RW, it is recommended that the movement of the KPM-1 (KPM-2) be organized: with a two-slope cross section - by the circular scheme, beginning from the longitudinal axis of the surface (Fig. 133a); with a single-slope cross section - by the shuttle scheme, beginning from the side of the upper edge of the surface (Fig. 133b).

With a wind velocity of more than  $10 \text{ m/s}$  directed along the longitudinal axis of the surface, the movement of the KPM-1 (KPM-2) should be only downwind, in parallel passes, with idling in the opposite direction (Fig. 133c). With a cross wind of more than

5-6 m/s regardless of the cross section of the surface, movement of the KPM-1 (KPM-2) is accomplished by the shuttle scheme beginning with the windward side.



The distribution of the aqueous solution of the reagent NKM on the RD is accomplished in two-three longitudinal passes of the machine depending on the width of the spreading. With atmospheric precipitation in the form of freezing rain or drizzle, for the prevention of crust ice it is expedient to use the reagent NKM in the form of a powder with a norm of  $100 \text{ g/m}^2$  which, falling on the moist surface, forms an aqueous solution. Formed on the processed artificial surfaces during the period of the forming of crust ice is a layer of loose ice (as a result of a decrease in the solution concentration from atmospheric precipitation) which has poor adhesion with the surface. Such a layer of ice with a thickness of up to 3 mm is cleared by the metal brushes of the KPM-1 (KPM-2) in two passes and with a thickness of more than 3 mm - in three or four passes. It is expedient to organize the movement of the machines in removing the ice

by the ring scheme for the entire length of the RW, beginning with the longitudinal axis, so as to first clear a minimum width of RW (30-40 m) to assure the forced take-offs and landings of airplanes.

The rate of melting and the quantity of molten ice depend upon the air temperature, quantity of reagent NKM spread, and the thickness of the ice. With an increase of air temperature and increase in the expenditure of the reagent, the process of melting the ice is accelerated.

The maximum effect of the melting of the ice by reagent NKM is attained at an air temperature of from 0 to  $-8^{\circ}\text{C}$ . At lower temperatures, the activity of the reagent is slowed down significantly and at a temperature of  $-12^{\circ}\text{C}$  the melting of the ice practically ceases. The time of the active interaction of the reagent NKM with the ice is within the limits of 15-60 min depending on the air temperature.

The technology of the use of the NKM reagent consists of two basic processes:

- 1) the distribution of the powdery reagent over the surface of the ice;
- 2) the removal of the residue of ice and brine from the artificial surface.

Reagent NKM in powder-like form is spread by sand spreaders of type KDM-1, PD-7, D-307A and machines similar to them. The basic requirement in the distribution of the adopted norms of expenditure of the reagent is its uniform distribution on the surface being treated.

The sprinkling density (spreading norm) depends upon the speed of movement and type of sand spreader. The actual sprinkling

density with various speeds of movement is established experimentally by the test distribution of the chemical reagent. According to the experimental data, it is advantageous to construct a graph of the dependence of the sprinkling density on the speed of movement on which the speed of movement of the machines to provide for the given norm of expenditure of the reagent is subsequently established.

The motion of the sand spreaders during the distribution of the NKM reagent is organized by the ring scheme, beginning from the longitudinal axis of the RW. With the simultaneous spreading of the reagent by several machines, their movement is organized by "bearing" (staggered) with the overlap of the strip of distribution by 0.2 m. The residue of destroyed ice and brine is removed from the surface by the KPM-1 (KPM-2) machines.

The chemical reagent NKM in powdery form and in a solution is not toxic, does not cause corrosion of the metal, and it is harmless to the skin; however, one ought to avoid its direct landing in the eyes and mucous membranes. Technical personnel working directly with reagent NKM should be provided with special clothing (mittens, rubberized aprons, etc.).

#### § 99. MACHINES FOR THE WINTER MAINTENANCE OF THE AIRFIELD

The large volumes of work in the winter maintenance of the airfield and the compressed periods for their conduct require contemporary highly productive means of mechanization: snow-removal and snow-compacting machines and machines for the removal of ice and crust ice formations from the artificial surface of the airfields.



Used as snow-removal machines on airfields are endless snow rotary snowplows, small-size rotary cutting snowplows, and plow-type snowplows mounted on trucks and combined street sprinkling and washing vehicles. The latter can be equipped with rotational sweeping brushes. Endless snow rotary snowplows are intended for the removal of the snow from the RW, RD, and MS of aircraft and approach and intra-airfield roads and are used for: the removal of freshly fallen snow; the moving of the snow, first piled with plow-type snowplows; the loading of the piled snow into means of transport (dump trucks, specially equipped cargo vehicles).

The endless screw rotary snowplow is a special self-propelled vehicle, the operating units of which (endless screw feeder and rotary thrower) together with the power unit are mounted on a vehicle or special chassis. The endless screw rotary snowplows used on airfields, the D-470 and D-450, are shown in Fig. 134. In the future it is proposed to use on airfields new modifications of these machines which have trade marks D-707 and D-902.

Small-size rotary-cutting snowplows (Fig. 135) are intended for the removal of the snow from the aircraft parking places (with the presence of aircraft at the places), sections occupied by landing lights, and other areas with tight working conditions, and also for the loading of the piled snow into the transport means. The operating unit of the small-size rotary-cutting snowplow, in contrast to the endless screw rotary plow, has a cutting feeder. This machine is mounted on a special self-propelled single-axle chassis.

Plow-type snowplows are intended for piling snow during their joint operation with rotary snowplows and also the patrol clearing of snow from the runways (with a thickness of snow cover up to 5 cm) and other elements of the landing area of

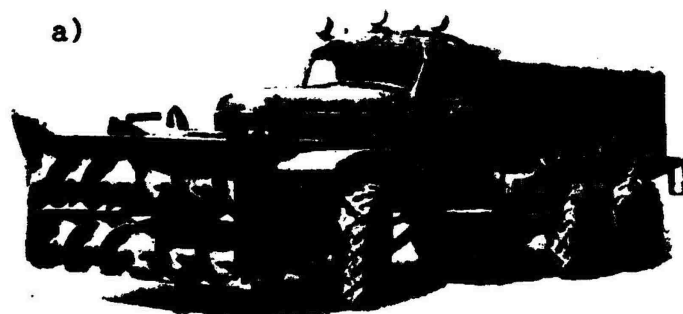


Fig. 134. Endless screw rotary snowplows:  
a) D-470; b) D-450.

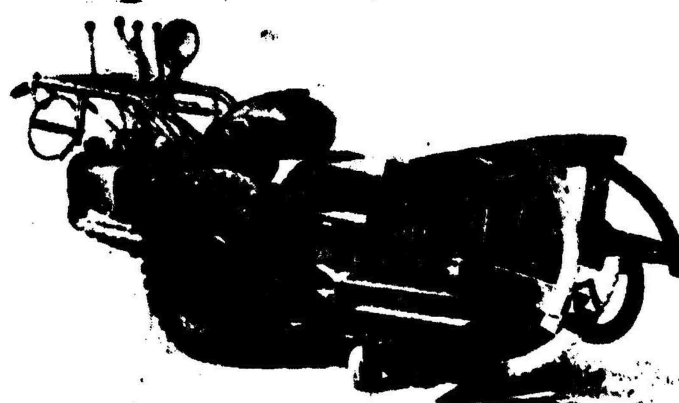


Fig. 135. Small-size rotary cutting snow-  
plow MS-59.

the airfield. Used on the airfields are vehicle-mounted plow-type single blade snowplows D-229 and L-366, plow-type single blade snowplows mounted on vehicles KPM-2 and KPM-64, and also the tractor plow-type double-blade snow-plows mounted on the S-100 tractors.

For the snow-removal work on aircraft MS and under the other cramped conditions plow-type single-blade snow-plows T-3 (Fig. 136) mounted on UAZ-69 vehicles are used. The plow-type snowplows mounted on combined street-sprinkling and washing vehicles KPM-2 and KPM-64, and also small-size snow-plows T-3 are used simultaneously with the metal sweeping brushes available on these machines. Tractor plow-type double-blade snowplows are allowed to clear the snow from artificial airport surfaces only in the case where their caterpillar running gear is equipped with special rubber cover plates.

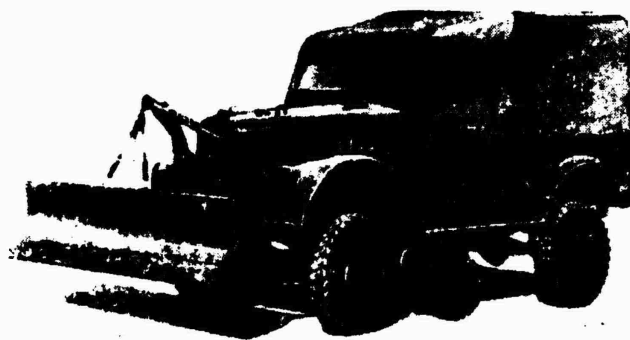


Fig. 136. Snowplow T-3.

Towed pneumatic rubber rollers (Fig. 137), towed cylinders (Fig. 138), and also smoothers made by the forces of the airport service are used as snow-compacting machines and mechanisms on airfields. Snow-compacting machines are intended for the layer-by-layer packing of snow on the sections of the landing area of airfields, the winter maintenance of which is performed by the packing method.

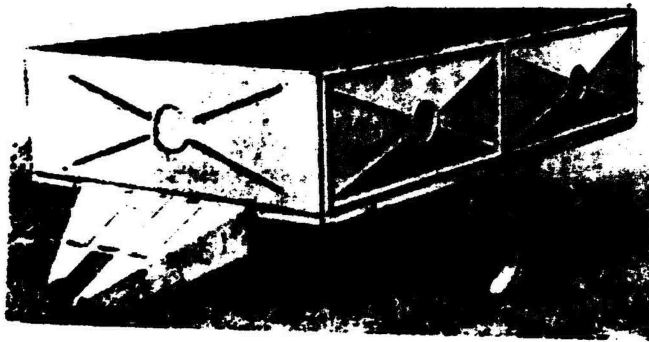


Fig. 137. Towed roller D-219 on pneumatic tires.

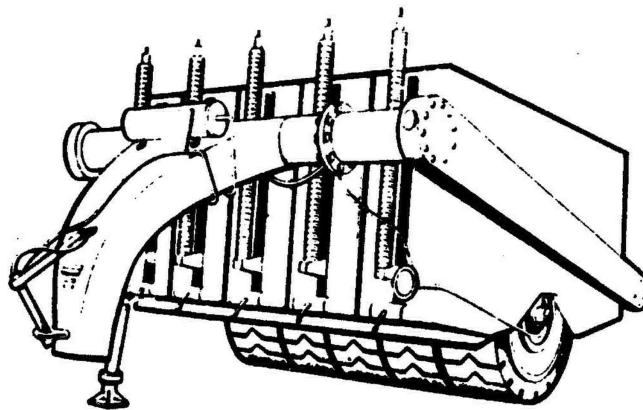


Fig. 138. Towed roller D-326 on pneumatic tires.

For the removal of ice and crust ice formations from the artificial surfaces of airfields heat machines of the type TM-57 and TM-59 are used. Heat machine TM-59 (Fig. 139) is mounted on a self-propelled D-452 chassis and has as an operating unit a jet aircraft engine equipped with an attachment for the direction of the gas jet over the airport surface. The removal of ice and crust ice formations is ensured by their melting and the blowing away of the formed water and water vapors by the gas jet of the jet engine.

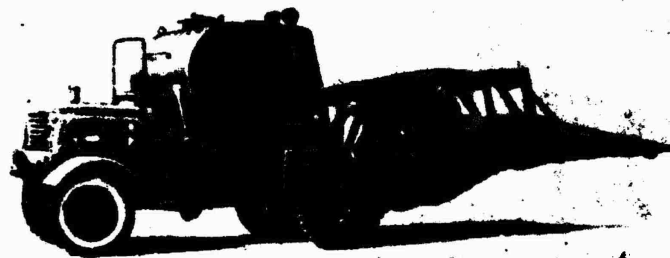


Fig. 139. Heat machine TM-59.

The best effect is attained with a thickness of ice of not more than 2 mm.

## CHAPTER XXIV

### THE MAINTENANCE AND REPAIR OF INTRA-AIRPORT AND ACCESS ROADS

#### § 100. THE MAINTENANCE OF AUTOMOBILE ROADS. CHECKING THEIR MAINTENANCE AND REPAIR.

The basic task of the operational maintenance of roads is assuring the year-round, uninterrupted, safe movement of transport means on roads. For this it is necessary to conduct systematically work on maintenance of the roads and their repair without stopping traffic over them.

The basic requirements for the organization of the maintenance and repair of roads include: clear and operational planning which makes it possible to establish the volumes of work and materials, periods for the accomplishment and the cost of the work; timely provision of a work force, machines, equipment and building materials; the use of integrated mechanization and the flow method for the maintenance and repair of roads and the conduct of the systematic technical accounting of the state of the roads and the checking of the accomplished work.

The basic documents for the correct organization of the maintenance and repair of motor roads are the technical data sheet of the road and the planning schedule for the organization of the work. The technical data sheet determines the actual

condition of the motor road and the road structures for the entire period of their service. The road data sheet is prepared as of 1 January of each year with the indication of all changes and repair and maintenance work accomplished during the past year. It contains a diagram of the road to a scale of 1:10,000 and a card on structures which permit water to pass through.

The diagram includes information about the length and technical condition of the roads, the location and length of the swollen, inundated, landslide, and crumbling sections of roads, data on the liability of the road to snow drifts and information about the road-repair work accomplished and its checking and acceptance.

The card on water-passing structures contains information about the location of the structures and their technical state, data on the nature of the current of water, calculated highest water level, dates of ice formation, debacle, high water, and volumes of repair and restoration work accomplished.

All road-repair work planned for the current year is reflected in the planning schedule. In it is indicated the list of operations, their form and volume, the periods of accomplishment, and requirements for labor force materials and mechanisms. Simultaneously plans and flow sheets for the organization of the repair work are worked out. Operational subdivisions prepare monthly plans which include work on the maintenance and repair of motor roads and structures.

The maintenance of motor roads and road structures depends upon the season of the year and is subdivided into two groups. The first group encompasses measures for the operational maintenance of roads and structures in the spring, summer and autumn. The second group provides for the maintenance of motor roads during the winter period. The operational maintenance of

roads and road structures in the spring, summer and autumn provides for work in assuring the draining and passage of high water through water-passing structures, care of the dirt road bed and surface, and the conduct of measures to prevent swelling.

In areas with a stable sub-zero temperature, after the termination of snow storms in the spring the openings in the pipes are opened, and the channels above and below the structure is cleared of snow, which facilitates the passage of the thaw water. In cleaning the channels the snow trenches are dug at least 30 m long from both sides of the structure. Then side ditches and raised and drainage ditches are cleared of snow beginning with the low points upward along the slope in order not to cause the damming of water capable of flooding the road. The ditches are cleaned by mechanical ditch diggers, motorized road graders, or slopers fastened to the blades of the graders. Simultaneously with the clearing of the drainage systems, the shoulders and slopes of embankments and cuttings are cleared of snow, which assures the uniform thawing of the soil under the road bed and prevents the formation of swelling.

With the belated accomplishment of the indicated measures, swelling can occur at individual sections of roads. Swellings appear back in winter in the form of mounds, on flexible surfaces fine cracks and wet spots appear, and on rigid coatings - the displacement of the concrete slabs. With the passage of automobiles on flexible surfaces ruts and washouts are formed, and on concrete surfaces - sags and misalignments and the shifting of individual slabs.

To safeguard the road from damages induced by spring swelling, it is necessary to conduct preventive and repair measures. For this, during the period of bad roads traffic must be shifted to detours, and where the road has broken up from the swelling it is necessary to reinforce the surfacing. The



strengthening of the surfacing is accomplished by metal airfield plates, reinforced-concrete road slabs, continuous timber decking, brushwood mats, and also in the form of a layer of sand or slag with a thickness of 10-15 cm. At the end of spring, when the soil gets dry, the "reinforcing surfacings" are removed and the damaged places on the road are repaired.

Pertaining to some of the most critical operations in spring are the operations connected with the passage of high water under bridges. They include strengthening the wooden supports and ice-cutters and cutting out slits in the ice along the supports and ice-cutters, and also above and below them. During the debacle large ice floes are broken up prior to approaching the bridge by ice spikes fastened to poles, and by crowbars attached to ropes. With the formation of obstructions the ice is blasted so that a water-passing channel is formed. After the termination of the high water and the debacle, the bridges are thoroughly inspected and, if necessary, repaired.

The basic work in eliminating damage to the dirt road bed which occurred in spring and also the smoothing of the shoulders, the reinforcement and smoothing of the slopes, the clearing of ditches, and the repair of drainage structures are performed during the summer period. Special attention is devoted to the maintenance and repair of the shoulders, with disrepair of which road surfaces are broken up. During prolonged operation, ruts, hollows, washouts, build-ups and depressions are formed on the shoulders (Fig. 140).

Ruts and depressions on the shoulders occur as a result of driving automobiles up on the shoulders; washouts are formed during prolonged rains. To repair the shoulders systematic dragging and shaping of the surface are performed, which impart to it the proper gradient and evenness.

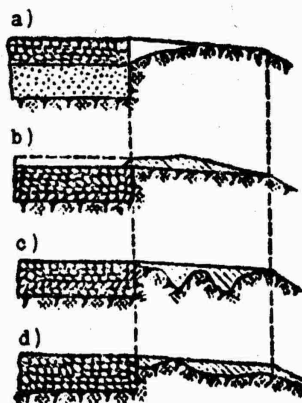


Fig. 140. Characteristic deformations of shoulders: a) the formation of a groove; b) build-up of shoulders; c) ruts; d) general deformation of shoulders.

The shaping of the shoulders is performed by graders and by motorized road graders.

The repair of the dirt road bed and road surfaces is performed mainly during the summer period. It includes the restoration of the profile of the dirt road bed and ditches and straightening and reinforcing washouts, slides of the slopes, and erosion by sodding or paving.

The repair of the rigid and flexible surfaces of roads is performed just as airport surfaces. In summer, great significance is had by combating dust and mud on the roads which impede traffic, increase the wear on rubbing parts of the automobile, and make the road dangerous for traffic. The major and improved surfaces of roads are cleared of mud and dust by street-sprinkling and washing vehicles. Simplified road surfaces are wetted by water, solutions of hygroscopic salts, and organic binding materials.

The maintenance of the roads in autumn consists of the preparation of them and the road structures for winter. In autumn, the motor roads are under most adverse conditions since a large amount of precipitation falls, as a result of which the soil is excessively wet, sharp changes in temperatures, leading to the

destruction of the surface layer occur, and mud appears. All this destroys traffic safety and should be eliminated in good time.

The basic operations in autumn are the clearing of dust and mud from the surfaces, the dragging of gravel roads, levelling the top of the dirt road bed, and the timely repair of shoulders and slopes. During this period, the repair work of drain systems is ended, the openings of low bridges and pipes in the areas of a stable winter are closed, the means of snow fencing are prepared, the repair of the floor of the bridges is organized, and the surfaces in the places of contact with the bridge floor are levelled off. The wooden construction of bridges (decking, stringers) affected by rot is replaced with new ones. Concrete and reinforced-concrete bridges are filled with concrete at places of damage (hollows, washouts). Simultaneously with road-repair work, in the autumn machines and equipment intended for the winter maintenance of the roads are prepared.

Road maintenance during the winter period is complicated due to low temperatures, snowfalls, snowstorms, snowdrifts, and crust ice. The loose snow cover and ice on the surface of the road considerably impede the traffic of the automobiles. With a thickness of the snow cover of 45-50 cm traffic on motor roads stops entirely. The icy slippery crust of ice reduces the adhesion of the tread of the automobile with road and destroys traffic safety. In a number of cases, with crust ice passage over the roads also stops completely.

The basic operations in the winter maintenance of roads include protection from snowdrifts, snow removal, and combating slipperiness. For the protection of the road from snowdrifts, use is made of snow-retaining devices and tree and bush plantings. Snow-retaining devices occur in the form of movable lattice panels, permanent fences and barriers of brushwood, and snow walls and embankments. The basic means of combating snowdrifts are movable

panels which require comparatively minor expenditures on construction and rapid installation and rearrangement from one place to another, and permit repeated rearrangement. Today it is recommended that panels be used with a spaced-out lattice in the lower part (Fig. 141). The panels are set up by fastening them to stakes, in "sheerlegs" and vertically in the snow without stakes (Fig. 142).

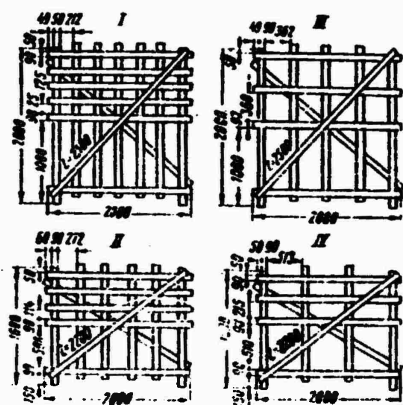


Fig. 141. Panels with spaced-out lower part.

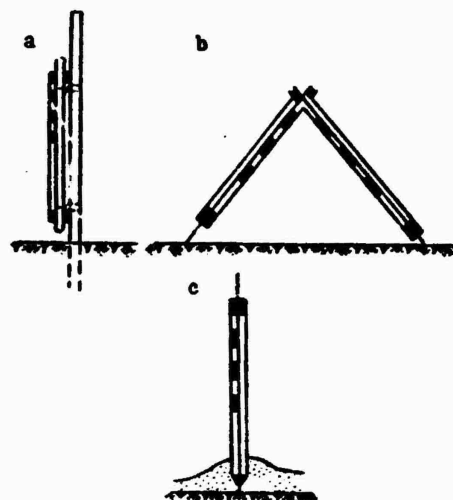


Fig. 142. Diagram of the setting-up of the panels: a - to stakes; b - in "sheerlegs"; c - vertically in the snow.

Tree and bush plantings are also an effective measure for snow protection. The planting of trees and bushes is performed along a road in one or several rows; the distance from the road to the living fence should be not less than 10-12 times the height of the fence.

The snow fence does not completely eliminate the deposition of snow on the road. Furthermore, snow falls on the road during snowfalls. Therefore, along with snow fences snow clearing is performed on roads. Vehicle and tractor snowplows, bulldozers, motorized road graders, and also the simplest towed angle-iron

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dredges and levelling rollers are used for snow removal. Snow removal is accomplished on the principle of continuous patrolling, in which, during a snowstorm or snowfall, snowplows continuously accomplish passes over the allotted section of the road at a rate of 25-30 km/h. At such a running speed, vehicular plow-type snowplows throw snow to the side, evenly distributing it over a width of 3-4 m beyond the limits of the clearing strip. The embankments which were formed during snow removal are removed with the use of rotory snowplows which clear snow in a layer to 1.1-1.2 m. Patrol snow removal is usually used in clearing the snow from access roads to the airport. For the clearing of intra-airport roads, other methods are also used. With a thickness of snow up to 0.4 m and its density up to  $0.6 \text{ g/cm}^3$ , graders and motorized road graders are used. With a high density of the snow, bulldozers are used for snow removal. With the thickness of the snow up to 1.2-1.5 m plow-type tractor snowplows are used, the full width of bits of which without the side wings is 3.6 m, and with the wings - 7.3 m. In the absence of snow-clearing machines, the simplest towed snow clearing means are used - wooden (of logs and beams) and metal triangles towed by tractor.

An important task of the operational maintenance of roads in winter is combating slipperiness. The slipperiness of the road arises in the case where after a thaw rapid cooling sets in or if rain falls on a cooled surface. In this case a thin layer of ice (crust ice) is formed on the road. Furthermore, the snow surface of the road can become slippery from rolling by the wheels of an automobile. For dealing with slipperiness the surface should be sprinkled with abrasive materials which raise the adhesion of the tires with the road, such as sand, ashes, crushed slag, siftings, and the other materials with particles no bigger than 6 mm. The material is scattered by vehicular sand spreaders.

§ 101. THE MAINTENANCE OF RAILROAD  
SPUR TRACKS

Checking Their Maintenance and  
Repair. Accident Prevention

The task of routine maintenance is to assure the constant working order of the railway line, prevent the appearance of defects, and assure prolonged period of its service.

The quality of routine repair depends upon the correct planning and organization of track work, for which it is necessary to determine sufficiently correctly their types and volumes, to establish the time of their accomplishment and to support the work with building materials.

To disclose the types and volumes of work for routine repairs, continuous inspection of the tracks for their entire length is necessary.

During the inspection, they check the conditions of the tracks, expose defects and establish their causes. For an improvement in the quality of the check, it is necessary to use track-measuring trucks and rail flaw detectors. For the inspection and testing of the track specific periods have been established. The dirt road bed, superstructure, artificial structures, and switches are inspected once every half month. During rains and high water, the tracks on which bulges have formed are checked as needed. Under bad weather conditions, in exceptional cases continuous attendance is established.

All defects of the superstructure of the track, dirt road bed, and artificial structures are noted in a book for recording the results of the inspection of the track and structures. Indicated in it is the work which it is necessary to accomplish for the

elimination of the defects of the track which were revealed in the inspection and periods are established and the time for the accomplishment of the work is noted.

The routine maintenance of the track has been assigned to track crews, track and bridge lengthmen and crossing guards. For a more complete and high quality accomplishment of all work, the sectionman together with the gang foreman of the track should prepare a schedule on routine maintenance and the evaluations of the track and track devices.

In this schedule urgent and preventive work are distinguished.

The urgent work includes work in the elimination of the inadmissible deviations in the gage maintenance, revealed with the use of a level and template, the elimination of the stagnation of water in ditches, and the other defects.

Preventive work includes work on the levelling of shoulders, partial replacement of ballast, individual replacement of the ties and crossing timbers, replacement of clamps, adjustment of rail clearances, and others.

There is unexpected work which is not planned with the schedule. It includes the elimination of defects which threaten the safe movement of trains. Such work includes the replacement of an acutely defective rail, elimination of an abrupt misalignment of the track, the repair of switch frogs and others. Unexpected work is accomplished immediately.

Track crews conduct routine maintenance of the track continuously during the entire year. In spring they prepare a drain to pass water, remove the snow from the slopes of the dirt

road bed and ballast prism and clean mud from the rails, fastenings and ties. Then they begin the "cursory" straightening of the track, which includes driving in the spikes, lubricating and fastening the track bolts, tightening up the wood screws, and the reinforcement of the nuts of the bolts. When the ballast prism thaws out for its entire thickness, the straightening of the track and joints is performed and unserviceable ties are replaced. Summer is most favorable for repair work which, during other periods of the year, is difficult or impossible. In summer, accomplished mainly is preventive work directed to the general improvement of the railway track. Preventive work is conducted on each kilometer of track and includes in the summer period, besides that listed above, such work as the replacement of unserviceable ties, the adjustment of clearance, the levelling of the shoulder, the cleaning of ditches and inspection pits, and continuous replacement of ballast in the places where bulges were formed in winter.

The primary task in autumn is the maintenance of track repaired in summer in good condition until the onset of frosts. The autumn work includes partial straightening and gauging of the track, the lubrication of the track bolts and clamps, and the levelling of the ballast prism and the shoulders of the dirt road bed. At the same time work is accomplished in preparing the track for winter conditions and protection from snowdrifts. The supply of rails at each kilometer is replenished, and tools used for the winter maintenance of the track are repaired.

In winter, the ballast layer freezes and therefore it is difficult to perform any work in the straightening of the track. However, with the appearance of individual defects even in winter time it is necessary to conduct preventive work. It is necessary to inspect the rails especially thoroughly in winter, since defects of rails are formed more frequently with a temperature decrease. In winter time, the joints of the rails are cleared



of snow and track devices for the automatic blocking system and electrification, the track bolts are reinforced, and snow fences and panel lines are installed.

It is necessary to devote special attention during the entire year to the maintenance of rails and switches which are the most critical elements of the superstructure of the track.

The safety and uninterrupted movement of the trains depends primarily upon this.

In the maintenance and repair of the track and the protection of the places with obstructions one should be guided by "Instructions on Current Maintenance of Railroad Tracks" and "Instructions on Safeguarding the Movement of Trains During the Conduct of Track Work" of the MPS [Ministry of Railroads] USSR.

## CHAPTER XXV

### PLANNING, REPORTING AND ACCOUNTABILITY ON THE MAINTENANCE AND REPAIR OF AN AIRFIELD

#### § 102. PLANNING THE WORK

The basic technical information about the airfield and structures on it necessary for daily operation is concentrated in a report on the state and basic characteristic of the airfield, buildings, structures and the airport equipment of civil aviation which is prepared at every airfield accepted for operation. This report reflects all the information about the dimensions, construction of the elements, and structures of airfields necessary for operation.

To account for the work in the maintenance and routine repair of the structures of the landing area a log of daily observations of the airfield is maintained in which entries are recorded about all discovered defects and work accomplished in the maintenance and routine repair with the indication of the type of work and place.

Apart from daily observations, the structures of the landing area of the airfield undergo periodic general and partial inspections. With the general inspection all elements of the landing area of the airfield and their structures undergo

examination, while with a partial - the individual elements of the landing area and their structures. The general inspections of airfields are conducted twice a year: in spring and in autumn. The general inspection of the structures of the landing area of the airfield is conducted by a board appointed by the commander of the joint aviation detachment or by the chief of the airport. As a result of the inspection, the board prepares reports in which the nature of damages and the types of repair work are noted.

On the basis of the reports of the inspection of the structures of the airfield, annual planning schedules for the repairs of the elements and structures of the landing area are prepared. The annual planning schedules are approved by the commander of the joint aviation detachment or the chief of the airport. In this, the overall volume of major repair should correspond to the plan approved by the higher organization - the territorial administration or the Ministry of Civil Aviation of the USSR.

The annual planning schedules established the periods for the conduct of routine and major repairs with breakdown by months and 10-day periods. Work on the repair of airfields should be tied to the schedule for traffic of the aircraft. As far as possible the major repair of airfields is planned taking into account the seasonal load of the airport, i.e., during the periods of the minimum intensity of flights. The planning schedules should be prepared taking into account the termination of all work on routine repair of the landing areas, artificial surfaces of the RW, RD, MS, access roads, the drainage and run-off systems, and the buildings and structures of the technical-service building system at the beginning of winter operation.

The record of the work accomplished in the operational maintenance and routine repair of airfields and expenditures of labor force, machines, and equipment is maintained in the log.

All work accomplished is entered in the log daily. Besides the designations and types of work, also noted in the log are the amount of work accomplished, expenditures of labor force in man-hours and machines in machine shifts, and also the expenditure of building materials. An entry is made separately for each element of the landing area and for each building and structure.

"Approved"

\_\_\_\_\_  
(signature)

"\_\_\_\_\_" \_\_\_\_\_ 19

REPORT No.

Object No. \_\_\_\_\_ "\_\_\_\_\_" \_\_\_\_\_ 19

Board consisting of \_\_\_\_\_  
(indicated are duties, surnames, initials of  
the members of the board)

operating on the basis \_\_\_\_\_  
(indicated are the authority of the board,

No. of order and instructions) \_\_\_\_\_

conducted from  
the period of "\_\_\_\_\_" \_\_\_\_\_ 19 through "\_\_\_\_\_" \_\_\_\_\_ 19

an inspection \_\_\_\_\_  
(the name of structure)

to disclose damages and shortcomings in the operation of individual  
elements and structures.

On the basis of an actual inspection \_\_\_\_\_

\_\_\_\_\_  
(structures as a whole or its elements)

\_\_\_\_\_ the board established that as a result of  
\_\_\_\_\_ (the reason which caused the formation of  
a defect) the performance of the following repair work is required:

1. \_\_\_\_\_
2. \_\_\_\_\_
3. \_\_\_\_\_
4. \_\_\_\_\_

The chairman of the board

\_\_\_\_\_  
(signature)

The members of the board

\_\_\_\_\_  
(signature)

"\_\_\_\_\_" \_\_\_\_\_ 19

**LOG**  
of daily observations of the airfield

Section of air-field	the date of observations	discovered defect	on what area	the reason for the appearance of defect	the necessary work for elimination of defect	periods for the accomplishing of the work	remarks about accomplishment
Airstrips.....							
RW.....							
RD.....							
MS.....							
Apron.....							
Overshoot strips							
Safety strips...							

**LOG**  
of work accomplished

Section of airfield	type of defect	types of work on elimination of the defect and their volume	periods for accomplishing of work	expenditure of work force, man-hours	expenditure of machines, machine-shift	remarks on accomplishment
Airstrips.....						
RW.....						
RD.....						
MS.....						
Overshoot strips.....						
Safety strips.....						

Building materials, metal and reinforced-concrete plates, grass seeds, mineral fertilizers, tools, and equipment manufactured by their own forces are considered in the log for the accounting for assets. Entry in the record log is accomplished regularly as building materials and other types of property arrive or decline. It reflects the name, number, and date of the receipt-expenditure document, the amount of building material and property which arrived or departed, the cost of a unit and its overall cost. Building materials can be stored both at a warehouse and at the objects subject to repair. Therefore, the book provides columns in which the presence of building materials is shown both at the warehouse and at the objects.

All remarks and indications of the checking officials are entered in the log of remarks and instructions which is maintained in arbitrary form. Entered in the journal is the date of examination, the nature of discovered shortcomings in the operational maintenance and routine repair of the airfields, and instructions and times for their elimination. The elimination of the shortcomings in the maintenance and routine repair of airfields noted in the log is mandatory for accomplishment. With the accomplishment of the noted shortcomings the corresponding entry is made in the log with the indication of when and by whom the instruction for the elimination of the shortcomings has been accomplished.

A board is designated for the acceptance of the executed work on the object as a whole. In accepting the work the board selectively checks the volume of the work accomplished, its quality and conformity to the approved planning schedule, and it also prepared a report of acceptance of the accomplished work. In the report, the board indicates the designation, quantity, cost and time for the performance of the work on routine repair. The report also notes the designation and the quantity of materials expended on the accomplishment of the volume of work.

### § 103. REPORTING AND ACCOUNTING

In conducting work on the maintenance and repair of an airfield considerable monetary resources, materials, fuel, motor potential of the mechanisms, and also a large quantity of labor of the servicing personnel are expended. Therefore, it is very important to keep records and accounts on this work correctly. Such reports, as a rule, are prepared twice a year - for the first half-year and for the entire year as a whole.

The main source document for the compilation of the report is the log of accomplished work and expenditures of labor force and machines which is maintained during the accomplishment of this work.

The report on the accomplishment of the plan for the routine repair and maintenance of the airfield consists of three sections:

- I - the use of resources (thousands of rubles);
- II - the accomplishment of the annual plan;
- III - the maintenance of the airfield in the winter-spring period.

The first section of the report provides an analysis of the expenditure of monetary resources and building materials issued for the routine repair and maintenance of the airfield. This section shows the remainder of monetary resources and of building materials at the beginning of the year, their arrival during the reporting period, the resources expended during the reporting period, and also the remainder of monetary resources and building materials at the end of the reporting year.

The second section of the report consists of two basic subsections: 1) the accomplishment of the plan for routine repair;



2) the accomplishment of the plan for the operational maintenance of the airfields.

The first subsection reflects the accomplishment of the plan in physical indices for routine repair of the artificial surfaces, landing areas, drainage and storm sewer systems of airfields, access roads and intra-airfield roads, airfield buildings and structures, objects of external systems (water lines, sewers, electrical nets), etc.

The second subsection reflects expenditures for planting and the organization of public services on the territory, the construction of temporary structures, expenditures for the salaries of the technical engineering personnel and works, expenditures for inventorying and introducing a passport system at the airfield, expenditures for the acquisition of technical literature, and other types of expenditures.

The third section of the plan provides an analysis of the maintenance of the airfield in the winter-spring period and shows the area processed cleared and compacted on airfields, how much snow has been removed and how many hectares have been compacted with expenditures of machine-shifts of rotary snowplows and combined street-sprinkling and washing vehicles, and how much of the entire labor force has been expended in man-days.

The completed work on the major repair of the elements and structures of the air movement area of the airfield is presented for acceptance by the organization which accomplished the repair work. To become familiar with the technical planning documentation and to inspect and check the volume and quality of the work accomplished on major repair, the chief of the airport appoints a board which, after completion of the acceptance, prepares a report following the form established by the Ministry of Civil Aviation of the USSR.

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